Charles T. Jackson
Boston

GEOLOGY FOR BEGINNERS.

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THE AGE OF REPTILES.

GEOLOGY FOR BEGINNERS

BY

G. F. RICHARDSON, F.G.S.

[illegible]

[illegible]

[illegible]

Second Edition

LONDON:

LONGMAN, BROWN, GREEN, AND LONGMANS,

PATERNOSTER ROW.

NEW YORK: WILEY AND PUTNAM.

1843

GEOLOGY FOR BEGINNERS.

BY

G. F. RICHARDSON, F.G.S.

OF THE BRITISH MUSEUM.

Memnonium, or Head of Rameses, in the British Museum, showing the passage of greenstone into syenite.—Page 206.

"It cannot be too extensively known that nature is vast, and knowledge limited, and that no individual, however humble in place or acquirement, need despair of adding to the general fund."—HUGH MILLER ON THE OLD RED SANDSTONE.

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6

GEOLOGY FOR BEGINNERS;

COMPRISING

A FAMILIAR EXPLANATION

OF

GEOLOGY,

AND ITS ASSOCIATE SCIENCES,

MINERALOGY, PHYSICAL GEOLOGY, FOSSIL CONCHOLOGY,
FOSSIL BOTANY, AND PALÆONTOLOGY.

INCLUDING DIRECTIONS FOR FORMING COLLECTIONS, AND GENERALLY
CULTIVATING THE SCIENCE, WITH A SUCCINCT ACCOUNT
OF THE SEVERAL GEOLOGICAL FORMATIONS.

BY

G. F. RICHARDSON, F.G.S.,

OF THE BRITISH MUSEUM,

TRANSLATOR OF THE LIFE AND WRITINGS OF KÖRNER; AUTHOR OF
SKETCHES IN PROSE AND VERSE, &c., &c.

LONDON:

LONGMAN, BROWN, GREEN, AND LONGMANS,

PATERNOSTER ROW.

NEW YORK: WILEY AND PUTNAM.

1843.

TO

JOHN HENRY, DUKE OF RUTLAND, K.G.

&c., &c., &c.,

ONE OF THE TRUSTEES OF THE BRITISH MUSEUM,

AND

A LIBERAL DONOR TO THE SCIENTIFIC COLLECTIONS OF THAT ESTABLISHMENT,

THIS

SECOND EDITION OF A WORK

WHICH IS HONOURED BY HIS GRACE'S PATRONAGE

IS, BY PERMISSION,

MOST RESPECTFULLY INSCRIBED,

BY HIS GRACE'S

MOST OBEDIENT AND MOST DEVOTED SERVANT,

G. F. RICHARDSON.

PREFACE

TO

THE SECOND EDITION.

The motives which originally induced the author to prepare this volume for the public were briefly these. During the course of some experience as a lecturer on geology, he had constantly been in the habit of recommending the various works already published on the science, and had as constantly been requested to name some treatise more particularly intended for the tyro, and more expressly designed to convey that preliminary information which the mere beginner is so anxious to acquire. Not being aware of the existènce of such a production, and being naturally desirous to comply with a demand so strongly and so extensively urged, he undertook the present publication; which, in addition to its claims on the attention of the novice, its adaptation for the use of schools, and of classes in literary and scientific institutions, would, it was hoped, be found not wholly devoid of interest for those who had already attained some proficiency in the science.

The flattering approval of the public press, the favourable manner in which the volume was received by the public, and the sale of a large impression in a comparatively brief space, have proved the correctness of these anticipations, and have induced the author to publish the present edition; which, beside a large increase of letter-press, contains a new frontispiece, with nearly one hundred new wood engravings, and is offered to the public at a reduction of two shillings in price.

The writer thinks it proper to mention that the whole of the additional wood-engravings were drawn, as well as engraved, by Mr. G. H. Nibbs, with the single exception of the vignette in the title-page, for which he is indebted to the pencil of Miss Plowman.

In submitting the volume to the public, the reader is again respectfully reminded that the work is one of the most elementary character,—that it is designed merely as an introduction to others of far superior merit,—and that the highest objects of the writer will be attained, if, by means of its pages, the reader should become acquainted with the admirable and judicious reasonings of a Buckland,—the philosophic speculations of a Lyell,—the splendid oratory of a Sedgwick,—the fascinating eloquence of a Mantell,—the talented writings of a Phillips,—the able and energetic re-

searches of a Murchison,—the instructive publications of a Fitton, a Delabeche, a Bakewell, and of many, many more, of whom science and literature may be justly proud, and who may be regarded as ornaments to letters and philosophy, and benefactors to the whole family of man.

DESCRIPTION OF THE FRONTISPIECE.

This delineation, which was designed, drawn, and engraved on the wood by Mr. Nibbs, represents the shores of that ocean by which the strata of the oolite and lias were deposited. Rocks appertaining to these formations constitute the heights and cliffs; and the vegetation consists of those trees and plants the remains of which are discovered in these deposits, including palms, tree-ferns, pandani, and coniferous trees; together with the smaller plants, as the ferns, cycadeæ, &c., &c.

The reptiles comprise the ichthyosaurus in the act of devouring a fish; the plesiosaurus, which has seized a pterodactyle, or flying reptile, on the wing; together with crocodiles and alligators, which are depicted on the shores. Turtles and tortoises are prowling on the banks, and the waters of this primeval sea are tenanted by corals, shells, crustacea, and fish, appropriate to this peculiar period of the history of nature.

The artist, it is obvious, has equalled the spirit and vigour of his design by the strictly correct and successful execution of its details.

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GEOLOGY FOR BEGINNERS.

CHAPTER I.

OUTLINE OF THE WORK—DEFINITION OF GEOLOGY—VINDICATION OF THE SCIENCE, AS A USEFUL AND PRACTICAL, AND NOT A MERELY SPECULATIVE AND VISIONARY PURSUIT—CONNEXION OF GEOLOGY WITH THE FOLLOWING IMPORTANT OBJECTS: NATIONAL AND COMMERCIAL PROSPERITY, MINING, THE DISCOVERY OF COAL, CIVIL ENGINEERING, AGRICULTURE, DRAINING, ARTESIAN WELLS, HEALTH AND SALUBRITY, ARCHITECTURE, THE ARTS, LITERATURE, MENTAL DISCIPLINE—EXERCISES ON THE ABOVE SUBJECTS.

Outline of the Work.—It may be desirable to state, at the commencement of this volume, the arrangement proposed by the author in its composition, which is, in substance, the same that he has found most eligible, when delivering lectures on the science. The present chapter will comprise a definition of geology; an endeavour to rescue the study from certain objections and prejudices undeservedly attached to its pursuit; and a vindication of its practical advantage, and its relation to the wants and utilities of life. The next will afford a brief outline of its history; and will be followed by others, conveying miscellaneous information, in the form of first lessons; together with directions for procuring and describing fossils, forming a collection, and generally cultivating geological inquiries. The succeeding chapters will respectively con-

tain an introduction to the auxiliary studies of Mineralogy; Physical Geology; Fossil Conchology; and Fossil Botany, with a few remarks on Palæontology; and the mind of the reader having thus been prepared with information on those studies, which are auxiliaries to the knowledge of nature and the acquaintance with geology, the remaining pages will be devoted to a concise description of the various geological formations; and of the phenomena of science as developed in the creation around us.

Definition of the Science.—Geology may be defined to be, the inqniry into universal nature, extending throughout all her kingdoms, animal, vegetable, and mineral; and comprising, in its investigations, all time, past, present, and to come. The present explains to us the past; the past and present reveal to us the future. The examination into existing geological phenomena, causes and effects, enables us to understand those which have occurred in past periods of our earth; to interpret nature by herself; and to appreciate agencies and results which are obscure and remote, by a comparison with such as are familiar and well known; while the study, both of the past and present, empowers us to deduce presages of the future, and to infer the nature of those changes and vicissitudes, which will, doubtless, occur on the face of our planet, during future eras of its physical history. It may be described, in a more compendious manner, as the investigation into the structure of the earth, and the nature of the animals and vegetables which have existed on its surface.

From the above definitions it will be perceived, that geology is by no means to be regarded as a mere single or isolated department of knowledge, but that

the pursuits which pass under this general name are, in fact, a combination of all the physical sciences, of all those studies which have the harmonies and beauties of nature as their object, and the perfections of her Divine Author as their ultimate end. From the magnitude and importance of the objects which it contemplates, geology may be considered as vying with the most exalted of the natural sciences in grandeur and extent; while, in the varied and attractive character of its investigations, it will be found to surpass them all. So diversified and so universal, indeed, is the sphere of its inquiries as to afford themes for contemplation, fitted for every order of mind; and while frequently, in the same object, it calls attention to facts which the infant understanding may comprehend, it offers problems for determination which the loftiest intellect is unable to solve. The shell imbedded in limestone, or the vegetable converted into coal, the mere child may perceive to be, the one a marine, the other a terrestrial production; but the process of the conversion of that shell into limestone, while the animal matter is often replaced by flint; or the agency by which the plant has been transmuted into a mineral substance, while the woody structure is still retained; each involves questions which the most advanced state of our knowledge is scarcely sufficient to determine.

In addition to other advantages which might be adduced, it must not be forgotten, that geology, notwithstanding the important advances which it has recently made, is still a youthful and a progressive study; all whose investigations possess the charm of novelty; all whose discoveries bear the gloss of freshness to recommend them. When Columbus revealed a new

hemisphere to mankind, the old world was eager and anxious to precipitate itself upon the new; and, when science discloses a fresh world beneath our feet, we cannot be surprised that all are eager and anxious to explore it.

Yet, even the variety, extent, and novelty of geological inquiry would never have procured for it so high a degree of popularity and favour as it has now attained; nor have enrolled among its students men of all ranks, from the peer and the philosopher to the labourer in the quarry, and the workman in the mine; were it not recommended by the more valuable advantages of practical utility, and application to many of the most essential wants and necessities of mankind.

Before the benefits of philosophic research and discovery were rendered so palpable and obvious as they are now happily become, it was the fate of this, like other scientific studies, to be regarded as a merely speculative and visionary pursuit, which, however well adapted to interest the philosopher in his closet, was utterly useless and uninteresting to the great mass of society. This erroneous opinion, though now, in a considerable degree, dispelled, is still so firmly implanted in the minds of many, who have not paid sufficient attention to the subject, that we shall deem it necessary to devote some of our earliest pages to a statement of the intimate relation of geology to several of the most important pursuits of life. To enumerate them all would far exceed the limits of an elementary treatise, and it will be sufficient to select from the whole, those examples which are best calculated to remove the mistaken impressions of ignorance or prejudice; and to substitute those more enlarged and accurate views which will de-

monstrate the practical usefulness of this valuable study, and justify the popularity and favour which it now so pre-eminently enjoys.

Dependence of National Prosperity on Geological Position.—It is a self-evident proposition that the social and commercial condition of entire communities is wholly based on their geological site and condition. To what, in fact, do we owe our own influential position, and our prosperity as a nation, but to those advantages so abundantly supplied by the physical geography of our island, which, by yielding us stores of metals and of ores, of limestones and of sandstones, of salts and of minerals, and above all of coal; and not merely by bestowing these, but by placing most of them in situations, and under circumstances best calculated to render them beneficial, enables us not only to supply our own wants, but to minister to those of others in distant regions, and to convey knowledge and civilization to the very ends of the earth? From the remotest periods, when the Carthaginians and Phœnicians traded with our British ancestors for lead and tin, to the present era, the mineral and geological resources existing in our native land have been eagerly sought by distant nations; and, at the present moment, countries, the most remote from our own, and from each other, are largely our debtors for many of the benefits which they enjoy. On the sultry plains of India, and of Arabia; and amid the frozen deserts of the north;—as far distant as the antipodes, and at every point between;—the natives are clad in garments, and assisted by tools and implements, which the natural resources of our country, aided by our commercial energy and enterprise, enable us abundantly to supply. Had these

advantages been less amply, less favourably afforded, not only should we have been unable to furnish the wants of others and to promote the cause of knowledge and improvement, but we should have been deficient in the supply of our own necessities, and should ourselves have continued in a comparatively degraded and uncivilized condition. If (it has recently been remarked with much force and justice*) the granite of the Scottish mountains had extended as far as the South Downs of Kent and Sussex; or if the chalk of our southern shores had reached to the Grampian hills, our social and commercial condition would have presented a dreary contrast to the scene of energy, enterprise, and wealth, which it now presents. If, on the one hand, the granite had prevailed throughout the entire island, we should have been placed in a country, picturesque, it is true, in its general outline, abounding in the alternations of mountain and of vale; of hill and of glen; relieved by the torrent, the waterfall, and the lake; and embellished with a profuse, though monotonous vegetation; while the rocks beneath would have afforded occasional supplies of precious metals, and yielded stores of tin, copper, silver, and gold. The climate, however, would have been severe; its productions limited and few; its population scanty, scattered, and poor; and we should have continued a race of miners and mountaineers. On the other hand, had the chalk extended over the whole country, we should have possessed extensive pastures and sheep-walks, and should have become a community of shepherds, grazing our flocks on the hills, and cultivating a confined and

* By Leonard Horner, Esq., at the Anniversary of the Geological Society, 1841.

partial vegetation in the valleys and fissures of the chalk. In neither case could we have attained that prosperity and eminence which we now so happily enjoy, since we should have been destitute of those natural advantages which constitute the basis of our national prosperity and power; and which, from the chalk of our southern shores to the granitic formations of the north,—from the South Downs of Sussex to the Grampian hills,—and from the clay lands of the east to the metallic districts of the west,—from the fields of Essex to the mines of Cornwall, yield a variety of benefits calculated not only to enrich ourselves, but to render us the dispensers of the best blessings to regions the most distant and remote. The relation of commercial and social prosperity to geological situation has been forcibly illustrated by Dr. Buckland, who, in his Bridgewater Treatise, furnishes an outline of the chief physical features of our native island, and calls attention to the striking fact, that no less than nineteen of the largest and most important towns in England, from Exeter to Carlisle, are all situated along the line of one geological formation, the new red sandstone, which, in addition to its own mineral treasures of rock-salt, gypsum, soda, and metallic ores, usually covers the invaluable deposit of coal, at once yielding an incentive and supply to the vast and enterprising population of this favoured district.*

* A passage of Scripture has been happily applied to describe the blessings with which we are favoured by our peculiar geological position.

"A land wherein thou shalt eat bread without scarceness, thou shalt not lack any thing in it; *a land whose stones are iron, and out of whose hills thou mayest dig brass.* When thou hast eaten and art full, then thou shalt bless the Lord thy God for the good land which he hath given thee."—Deut. viii. 9, 10.

Dr. Silliman, also, in his excellent introduction to the American edition of Dr. Mantell's Wonders of Geology, adverts to the same point, and with patriotic zeal expatiates on the admirable resources of the vast American continent, the variety and riches of its diversified geological deposits, and the favourable prospects of its future inhabitants.

This part of our subject is so varied and important, that to follow it in all its details would far exceed the limits of an elementary treatise; and with one additional remark, illustrative of our obligations on this account to an all-bountiful Providence, we shall pass to other observations of like nature. It is found that insular situations are usually favourable to the development of varied geological formations, while continents and extensive tracts of country are generally monotonous and unvaried. Thus, while the Isle of Arran presents a perfect epitome of the lower secondary and primary, and the Isle of Wight a like compendium of the tertiary and upper secondary formations, Mr. Murchison, in his recent visit to Russia, travelled for two thousand miles over old red sandstone alone. Hence, in addition to the advantages of natural security and defence, our insular position confers those of mineral resources alike diversified and beneficial. The same cause, or train of causes, which rent our island from the adjacent shores of Europe, was, doubtless, associated with intrusions of eruptive rocks, which brought with them to the surface, many of those varied and valuable deposits which now so largely enrich and bless our favoured country.

Geology connected with Mining.—Among those economical advantages which the science is calculated

to confer, its assistance to the miner may be first adduced, since it occurs earliest in the series of geological formations. It is at once the object and the boast of geology to redeem the search after metallic ores from the mere blind chance, or still more benighted superstition by which it has frequently been governed; to teach the miner, on the one hand, to discard the belief in sinister influences and evil spirits, and, on the other, to reject the delusion of the incantation and the divining rod; and, by showing that mineral substances have not been distributed at random, but that each is referable to some peculiar geological deposit, to direct the inquiry for them on fixed and enlightened principles, and in conformity with those laws of nature which regulate their occurrence. In this country, the granitic regions are the only districts, in which tin is discovered in sufficient extent and abundance to justify its being sought for economical purposes. Copper is also found in the greatest abundance in granite, and in the schistose or slaty rocks above it; and the principal mines of both these metals, in this country, are situated in Cornwall; though the latter substance also presents itself, but in less plenty, in the new red sandstone, and occurs in Staffordshire. Lead is chiefly confined to the carboniferous limestone, a deposit which usually underlies the coal, and the most important supplies exist in Derbyshire and Scotland, amid strata appertaining to this formation. These metals, together with silver and others, occur in veins, which, in some cases, communicate with fissures beneath, and have, probably, been occasioned by deeply-seated subterranean agency; or they are the result of the chemical segregation of metallic particles from the surrounding mass. Gold

offers an exception to the general rule of metals existing in veins: it is disseminated in minute quantities throughout those rocks (usually of a quartzose character,) in which it occurs, and is chiefly obtained in alluvial gravel resulting from the decomposition of such rocks, or from the sands of rivers, which, flowing over them, have washed out the particles of gold. Platinum, together with zircon, the diamond, and many other gems, is also found in alluvial deposits, their original source being, probably, the same as that of gold; while iron, in this country, is usually associated with coal and limestone, without both of which substances it would be impossible to reduce this invaluable ore to a metallic and useful state.

The veins of mineral substances are by no means of equal extent or value in all parts of their course, but the ore is distributed in local masses and aggregations, or *bunches*, as they are locally termed, along the line of its occurrence; while in the case of tin it frequently either spreads out into a flat mass, technically called a *floor*, or on the other hand thins into mere filaments or strings, and occasionally dies out altogether, leaving the miner to infer the path he should pursue from the occurrence of vein-stones or *shodes*, as they are called, which, though barren in themselves, are valuable as affording a clue to the re-appearance of richer deposits. These stones are partially rounded and apparently water-worn, and are found on the surface, or at very small depths below it. Their mineralogical characters nearly resemble those of the contents of the *lodes* or veins in the vicinity, of which they are presumed to be fragments removed by diluvial action. The proximity of veins is farther shown by certain

indications which rarely fail to point out their nearness to the surface. These are, the barrenness of the spot, the presence of shattered fragments of the stones above-mentioned, and, occasionally, the harsh, metallic taste of the water of some adjacent spring. Veins of copper are usually found in connexion with an earthy, ochreous stone locally termed *gossan*, which is of a red colour, and crumbles like the rust of iron. The peculiar substance called *killas*, which has been described as a gneiss that has lost its schistose character, and become comparatively easy and free to work, affords another symptom of their occurrence. The *lodes*, or veins, both of tin, copper, and other ores, exist most frequently in the vicinity of granite, which is called by the miners their *country*. Metallic veins, also, usually occur contiguous to axes of disturbance, and at points which exhibit proofs of the action of fire. Since these circumstances are chiefly of local nature and origin, and are dependent on the character of the individual formation to which they are referable, it will be seen from these, and numerous other instances which might be adduced, that mineral substances present themselves under such diversified conditions, and amid such varied difficulties of research and acquisition, as a right knowledge of geology, and of the distribution of the several deposits, can alone enable us to overcome.

Geology applied to the Discovery of Coal.—But there is a mineral substance more precious than silver, more valuable than gold, the occurrence and profitable discovery of which geology alone is able to determine, and that substance is coal. It is obvious that if the mines of the precious metals (unphilosophically so termed) were closed to-morrow, and gold

and silver no longer raised for the use of man, society, with some very considerable revolution and difficulty in the mode of adopting other imaginary representatives of value, would go on nearly as before; but deprive civilized communities of their coal, and how fatal would be such a catastrophe to the welfare and happiness of the great family of mankind! Not only should we lose with this substance the best means of maintaining the genial warmth of our personal temperament, and the health of our frames, as well as our cleanliness and comfort, but, from the scientific purposes to which our supplies of mineral fuel are now devoted, we should lose with the coal those advantages which, by the application of steam to the most essential wants of life, have raised us to our present eminent position as a people. No longer would our favoured country be the great factory for supplying the most important necessities of the whole family of mankind; no longer should we, with our commerce, convey the associate benefits of knowledge and civilization to the remotest regions of the globe; no longer should we all but triumph over time and space, and traverse the land with a rapidity which exceeds all anticipation and almost all belief, and the vast ocean with a swiftness and a certainty which brings the far East, or the New World itself, within the voyage of a few days: our steam-power would be annihilated, and with it our prosperity and supremacy as a nation; our steam-engines would rust disused for want of fuel and supply; our factories would be closed; our railroads would fall into disuse; our steam-ships would be dismantled; and the future historian of the revolutions of empires would date the decline and fall of the vast dominion of Britain from the

period when her supplies of mineral fuel were exhausted, and her last coal-field consumed!

That this is a calamity less remote than we may be accustomed to imagine, will appear from a consideration of the thinness and uncertainty of the seams of coal, as contrasted with the masses of rock with which they are associated. The attention of the public has, therefore, been called to the destruction of small coal, by burning it at the mouth of the pit, for want of a market; an evil which is now, however, remedied to a considerable extent, in consequence of the recent discovery of a method of forming it into cakes of fuel; while the policy of sending it to foreign countries has been so strongly questioned, that the present ministry have imposed a tax on its exportation. It is, however, just to state that opinions are divided on this latter point; and that while Dr. Buckland, both in his Bridgewater Treatise, and in his recent address in retiring from the chair of the Geological Society, denounced its export abroad in terms of equal severity with its destruction at home; other parties, of whom Mr. Buddle is one, advocate its unrestrained exportation, chiefly on the ground that, by imposing restrictions, we shall only stimulate other nations to discover it in their own territories, and thus to become independent of us for their supply.

Such are some of the most important benefits connected with the discovery and the use of coal; and coal is a substance which geology may be said to claim exclusively as her own. The utility of the science consists not more in pointing out those situations in which coal may be presumed to exist, than in determining those in which it cannot possibly occur; for while,

on the one hand, the limits of the coal-producing districts have been largely and beneficially extended, by means of researches undertaken in accordance with scientific views; on the other, enterprises have been commenced by persons ill-informed on the subject, which, being conceived and carried on in opposition to all sound geological principles, have terminated, as was inevitably foreseen by all men of science, in utter failure and disappointment. Some few years only have elapsed, since the deceptive appearance of lignite, or imperfect coal, in strata appertaining to the wealden formation, at Bexhill, in Sussex, on some land belonging to the Duchess of Dorset, induced certain parties, imperfectly acquainted with geological science, to prevail on her Grace to institute a search for coal; and it was not till after works of the most extensive and costly nature had been constructed, and an outlay of £10,000 incurred, that an enterprise, hopeless from the first, was at length abandoned in despair. Many attempts of like abortive kind have been made, from the county of Somerset to Wales; and Mr. Murchison, in his admirable work on the Silurian System, mentions numerous enterprises all similarly unsuccessful. In fact, there is scarcely a formation below the chalk in which researches of this kind have not been attempted. One of the most recent and the most ill-judged of these consisted in an endeavour made, a short time since, at the Kingsthorpe pits, within a mile of Northampton. The author was at that time lecturing in the neighbourhood, and his opinion was requested as to the probable success of the undertaking. The geological site of the locality, which is about the middle of the oolite formation, was decisive of the futility

of the enterprise, and he therefore denounced it as mistaken, and strongly protested against its farther prosecution. His remonstrances, as is usually the case on these occasions, were disregarded, as those of a mere theorist. It appeared that a person employed to sink a well near the spot, having bored through a bed of clay, which bore some slight resemblance to the *clunch* or clay which frequently overlies the coal, had advised the undertaking; and thus, on a fact of the most common geological occurrence, the similarity of one bed of clay to another, and under the guidance of an uneducated workman, the speculation was set on foot; a joint-stock company was organized; a large amount of capital subscribed by parties, many of them little able to sustain even a slight pecuniary loss; steam-engines were erected, shafts were sunk, and enormous expenses incurred. This was the situation of affairs during the visit of the author in 1839. The result may easily be anticipated: the works, after being extensively prosecuted, were finally closed, and the enterprise abandoned for want of funds, after an expenditure of £20,000! Such was the termination of an attempt which an acquaintance with the simplest principles of geology, as they will be detailed in future pages of this volume, would have decided, from the first, to be fruitless altogether. It will thus be seen that the power which the skilful geologist possesses to determine on the existence or non-existence of coal in any given locality, may be regarded as one of the most striking proofs of the importance and usefulness of the science.

Geology applied to Civil Engineering.—At the present day, when nearly the whole of the British Isles

is about to be intersected with railroads, and when these magnificent enterprises require to be conducted through districts the most diversified and dissimilar in geological site and structure, a knowledge of the general principles of the science, and of the physical geography of the region which is to be the sphere of the undertaking, are highly important to the engineer. The nature and composition of the different deposits, varying as they do from loosely coherent beds of gravel, sand, or clay, to rocks of crystalline texture and hardness, will often determine the choice between two proffered lines of road, or the course to be pursued in a certain district; for example, when the beds are loose and porous, they are frequently to be avoided; while, on the other hand, a rock, though hard and crystalline, may present a valuable stone for masonry, and may thus repay the cost of penetrating it, since an excellent supply is to be procured on the spot, for the mere expense of quarrying the material. A due acquaintance with this science would also prevent the repetition of those mistakes which have proved so prejudicial to railways, such as the forming deep cuttings in beds of London clay; a substance which, though sufficiently hard and trust-worthy during the summer, becomes so soft and yielding when saturated by the rains, and fractured by the frosts of winter, as to fall in, overwhelm the railway, and stop the traffic, to the great loss of the proprietors, and danger and inconvenience of the public. As regards the construction of these and other public works, an acquaintance with geology is, therefore, now found to be of such essential importance, as to constitute a part in the education of all who are destined for the profession of engineers.

THE CONNEXION OF GEOLOGY WITH AGRICULTURE.— The cultivator of the earth is, in like manner, benefited by that insight into the structure of the globe which geology is enabled to supply; for as the superficial soil is usually derived from the disintegration of the rock beneath, an acquaintance with the nature and chemical composition of those rocks cannot but prove of indispensable utility in pointing out the most successful mode of cultivation. Those lands are most productive, and least liable to exhaustion, which contain a due admixture of the three earths, clay, flint, and lime; but as the instances are comparatively few in which nature has bestowed the three substances in unison, it is the study of the scientific agriculturist to supply the deficient material, by the introduction of a counteracting substance; to correct, for instance, the moisture of clay soils, by the application of chalk and lime; and to remedy the dryness of sandy deposits, by a judicious tempering of clay. And lastly, by consulting a good geological map, and finding those districts the deposits of which are analogous to those of his own neighbourhood, and learning the mode of cultivation most successfully pursued in those localities, he may ascertain the kind of tillage best adapted to his own.

In the all-important operation of draining land, the knowledge of the strata of a district, and of the changes and disturbances which they have undergone, is alike calculated to be beneficial. A soil otherwise good may be rendered unproductive by resting on a bed of clay, under which is situated a porous stratum; and if the deposit of clay be thin, it may be bored so as to release the water, by guiding it into the perforation. The dislocations and faults of strata should also be studied

for the same object. In some cases these faults are mere cracks or fissures, pervious to fluids; in which case they may be made natural drains, to carry off the superfluous water. Occasionally they are filled with clay, or some similar substance impervious to moisture; in which case they retain the water, which bursts forth in springs at the sides of the fault. By piercing the interposed clay, it is often possible to carry off the water more effectually, and with less expense, than by draining each spring in succession.

ARTESIAN WELLS.—The inestimable benefit of water is another boon, which, under peculiar conditions of the district, geology enables the scientific agriculturist to obtain. The Artesian wells, so called from their being conceived, though incorrectly, to have been first introduced in the province of Artois, in France, have been so frequently brought before the notice of the public, that the simplest outline will suffice to convey an idea of the principle on which the invention is founded. The annexed diagram represents deposits appropriate to the tertiary system, suppose the valley of the Thames.

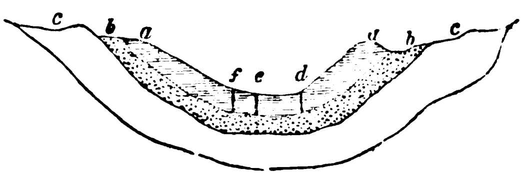


FIG. 1.—Artesian Well.

The bed, *a a*, is an impervious stratum of London clay; *b b*, a porous deposit of gravel or sand, both

resting on the chalk, *c c*; the whole forming a basin-like structure. The water which falls on the chalk-hills, *c c*, flows either into the chalk, or the porous bed above it, *b b*; and being forced upwards by fresh accessions, would rise to the top, were it not prevented by the clay above, *a a*. The geological engineer, by piercing either the bed, *a a*, or the chalk below it, releases the imprisoned fluid, which flows to the surface, and yields a copious and valuable store. The conditions are modified by local circumstances, but the above description will be found generally correct. A considerable change has recently taken place in the opinion of geologists and engineers, and whereas the beds above the chalk were formerly considered to yield the water, it is now conceived to be merely forced into them by upward pressure either from the chalk itself, or the *gault* or blue clay beneath, which are acknowledged to be the primary sources of supply. The chief advantage of this invention consists in the circumstance, that we are, by this means, enabled to procure copious streams of water from depths, and under conditions, which would either preclude the sinking a well altogether, or without such an expence as would impose a prohibition on the enterprise. The plan has been adopted with eminent success in the vicinity of our own metropolis: but the most important enterprise of this kind, is that which has recently been brought to a most successful termination in the Plaine de Grenelle, near Paris, where after boring to an immense depth, sufficient water is ejected in a few days, to supply all Paris for twelve months.

The Relation of Geology to Architecture and the Fine Arts.—Nor is the knowledge of this science

scarcely less essential to the architect and the student of the arts, since an acquaintance with its principles affords a sure guide in the important object of selecting a good and durable quality of stone, and avoiding a perishable and unworthy material. Many of our public edifices, both in the capital and the provinces, are fast hastening to decay; several of the colleges of our Universities have required to be nearly rebuilt; and many of the newly erected churches, that of St. Peter's, Brighton, among the rest, are in course of premature dilapidation, owing to the fragile and decomposing nature of the stone: while several of our ancient edifices which have become decayed, have been repaired with so faulty a material that old and new have speedily become one ruin. The Capitol, at Washington, in the United States, the finest senate-house at present in existence, is in a like state of disfigurement from the same cause. The evil, in fact, in this country, has grown to such a magnitude, as to have effected its own cure. The attention of architects and men of science has alike been called to the subject, and on the recent destruction of the Houses of Parliament by fire, a commission, as is well known, composed chiefly of geologists, was appointed by government to survey the stone-producing districts, and select the fittest materials for the construction of those edifices; the senate of the land thus bearing testimony to the value and importance of geology, as regards this beautiful and important art. The stone recommended by the commission, is one appertaining to the magnesian limestone formation; and thus, a material, previously little known or employed, beyond the local sphere of its immediate occurrence, is likely to be

brought into extensive use. In addition to this brief outline, the architectural student will find ample and interesting information in the report of the commission in question, with the annexed tables of the principal quarries, and of the chemical composition and other qualities of the stone; as well as in an able paper on the same subject by J. C. Smith, Esq., a member of that commission, published in the Transactions of the Royal Institute of British Architects.

Connexion of the Science with Sculpture.—The sculptor is no less indebted to geology, and its associate science, mineralogy, in the choice of a material for the exercise of his art. Some of the finest productions of the artist's skill, owing to the choice of an unworthy material, have become chipped or decomposed, and have thus lost the finest lineaments of the features and the most delicate graces of expression; or the stain occasioned by metallic admixture, or the impure character of the limestone, has veined or disfigured the most perfect productions of art. The Greek marble of Pentelicus was much disfigured from its impurity and admixture of metallic oxides; the Italian quarries of Massa and Carrara, which consist of an altered limestone, supposed to be of the oolitic series, are therefore preferred. Many ancient works of art are disfigured by the faulty nature of the material, and a celebrated *chef d'œuvre* of modern date, the Ariadne of Danneker, is spoiled from the same cause. It may be added, that the late Sir Francis Chantrey was so well aware of the value of knowledge of this kind, that he was himself a proficient in mineralogy and geology, and left a splendid collection; his performances are therefore faultless, as regards the quality of the material. Even where these

actual defects have not existed, the beauty and effect of a statue are known to depend, in a material degree, on the more or less crystalline character of the stone, and the efforts of the artist are largely dependent on the quality of the substance on which he is employed. We have only to place a cast in plaster, beside the antique statue from which it has been modelled, to perceive, to how important an extent the expression of sculpture is enhanced by the purity of the material of which it is composed. It may here be incidentally remarked, that many of our British marbles, those of Devonshire, Derbyshire, and Staffordshire, in particular, are exceedingly beautiful. They rival, in fact, those of Italy and Sicily, and, owing to the prevailing taste for everything foreign, are frequently sold for such.

To Painting.—We may farther adduce the pictorial artist as capable of deriving instruction of a highly valuable nature, from a science which teaches the physical geography of a country, and the principles which determine its scenery and aspect. Many paintings of celebrity and merit, in other respects, are irretrievably injured to the eye of taste, by departures from the truth of nature, which a knowledge of this science would have served to prevent. How absurd, for example, should we deem the error of that painter, who, if employed to depict some event which occurred in the southern district of our island, should array the scene in all the harsh and rugged features which characterise the primary formations of the north; as, on the other hand, how gross would be the mistake of the artist, who, in representing an occurrence which happened in our northern districts, should invest its stern and rugged outline with all the soft, undulating characters

which distinguish the southern scenery of our native land. Yet some of our most celebrated modern paintings exhibit faults as palpable as these, in which rocks are delineated and views pourtrayed in localities, where, owing to the physical geography of the district, they never could have existed.

RELATION OF GEOLOGY TO HEALTH.—The connexion of geological position with health, and the salubrity of particular spots produced by geological causes, are circumstances too obvious to require more than a casual mention here. The cleanly soil, clear air, and pure water of the chalk deposits, compared with the muddy ground, foggy atmosphere, and impure waters of the London clay formation; and the dry nature of a sandy region as contrasted with the dampness and malaria of a marshy spot, are all circumstances known and appreciated by medical practitioners, at least as regards their effects, though the causes may have possibly remained unnoticed by those of the profession who have not made this science their study.

The moral and social feelings of the inhabitants of particular districts are alike influenced by geological situation, and the enterprise of the islander, and the local patriotism and attachment to home of the mountaineer, and the native of primary districts, are (often without the consciousness of the parties themselves) inspired by the physical geography of their native region.

TO LITERATURE.—The connexion of geology with letters, is evident from the distinguished merit of the works of its most eminent professors. The publications of Buckland, Lyell, Mantell, Murchison, Phillips, Sedgwick, and others, are as much an honour to letters as they are to science; and the study, unquestionably,

owes much of its popularity and favour, among the most intellectual and influential classes of society, to the genius and the gifts of those who have made it so peculiarly their study. It would be invidious to particularise, but the selection of a few striking instances may perhaps be pardoned. There is scarcely a more beautiful or more perfect description than that in which Dr. Buckland* depicts, with his accustomed eloquence, a Silesian coal-mine with all its splendid scenery of the graceful vegetable forms of the primeval earth. Dr. Mantell,† adopting the image of an Arabian writer, introduces an imaginary being, endowed with superhuman longevity and power of observation, and, in the person of this fictitious observer, describes the chief geological mutations of our island in a style which combines the most perfect eloquence with the most accurate adherence to scientific fact. Mr. Lyell ‡ has a passage, which forms one of those gems of philosophic truth with which the pages of this admirable writer are so profusely adorned. After noticing the remark of Lord Byron,

> "The dust we tread upon was once alive,"

a sentiment, the counterpart of which is to be found in Dr. Young, Mr. Lyell admirably observes that the philosopher transcends the poet, and that while the one can only utter the vague exclamation that inanimate matter once was animate; it is the triumph of the other to describe the very form which it assumed, when endowed with all the faculties of existence. The

* Bridgewater Treatise, vol. i. p. 458.

† Wonders of Geology, fourth thousand, vol. i. p. 409.

‡ Elements, second edition, vol. i. p. 57.

works of Mr. Murchison abound in the most graphic descriptions of the wild and wondrous regions which he has so successfully investigated: those of Professor Phillips display the rare union of severe and minute investigation of facts, and mathematical accuracy of deduction, with the most graceful style of composition, and the most attractive charms of sentiment and feeling. A similar tribute is due to Professor Owen, to whose researches, memoirs, and publications, science is so deeply indebted; who, in his admirable orations, literally "bids the dry bones live," and invests the stern inquiries and strict details of anatomical and physiological investigations with all the attractions of eloquence, genius, and taste. The orations of Professor Sedgwick evince the like combination of scientific attainment with literary excellence; and the writings of various other geologists might largely increase our list. Mr. Hugh Miller* has a chapter, descriptive of the influence of physical geography on the character and aspect of natural scenery, which transcends, in force and beauty of description, any production of similar kind with which the writer is acquainted; while it exhibits, at the same time, that acquaintance with the principles of science, to which the mere delineator of scenery, of course, makes no pretension. The fame, indeed, of our scientific literature has prevailed as far as civilization extends, and the American Professor Silliman, himself a philosopher and orator of the highest order, revered and honoured in both hemispheres, exclaims, in a tone of generous admiration worthy of such a mind, "Who can write better than Lyell, Buckland, Mantell, and the other authors on the same science?" And echo may

* On the Old Red Sandstone, p. 197.

repeat the inquiry from this side the Atlantic, and may answer, "Who?"

MENTAL DISCIPLINE OF THE SCIENCE.—Indeed, the highest and the noblest advantages to be gained from this instructive study, consist not in considerations of benefit or of detriment, in questions of profit or of loss, for these we might pursue to a much greater extent, but in the intellectual advancement and moral improvement which it is so well calculated to promote, and in its power of invigorating the mind, and purifying and chastening the feelings and the heart. If, as who indeed can doubt, the celebrated aphorism of Lord Bacon be true; and if all study, as he affirms, is to be valued not so much as an exercise of the intellect, but as a discipline of humanity; in other words, not in proportion as it may render us more clever and more acute than others, who may possibly not have enjoyed the same advantages with ourselves, but as it makes us better as well as wiser, and advances us in the scale of moral as well as intellectual being; what study can be more instructive and improving than that which, by teaching us to look into the beautiful and harmonious world around us, corrects and chastens our overweening opinions of ourselves, removes and dispels our petty and inadequate ideas of nature, and substitutes more just, because more magnificent, views of the grandeur of creation, and the perfections of its great and infinite Author. The studious and the observant, the moralist and the divine, may deduce from its varied contemplations lessons of the highest wisdom and instruction; and our immortal bard, who has depicted almost every condition of human life, might seem to have had the modern geologist in view, and to have

described, with prophetic anticipation, his secluded but useful existence, and his unobtrusive but beneficial occupation, in the well-known passage—

> "And this our life, exempt from public haunt,
> Finds tongues in trees, books in the running brooks,
> *Sermons in stones*, and good in every thing!"

EXERCISES.

It may be necessary to premise, that the exercises proposed in the course of the following pages, will consist less of the formal arrangement of questions to be proposed, and answers to be returned, than of a recapitulation of the most important statements contained in each foregoing section, with the view of impressing them more strongly on the memory, and enabling the student to apply them in a practical manner.

It will be obvious, that subjects of so general a character as those contained in the preceding introductory chapter, are little adapted for purposes of this nature, yet a few instances may, perhaps, be transferred to the common-place book of the student, or may advantageously be borne in recollection.

1. Vary the definition of geology, by terming it, with Mr. Lyell, the inquiry into the materials of which the earth is composed, and the arrangement of those materials; with the collateral investigation into the races of animals and plants which at various periods have inhabited the globe; or describe it, with Professor Phillips, as the inquiry into the nature of sedimentary deposits, and their disturbance by igneous action, together with the natural history of animals and vegetables, &c. &c.

2. Collect instances of the practical application and importance of geological science, under local circumstances, in addition to the instances here described.

3. Give individual examples of the influence of geological site and position on the character of the inhabitants of peculiar districts, as, for instance, the energy of the islander, the local attachment of the mountaineer, and the commercial spirit of the inhabitants of those districts which produce coal. The relation of the same causes to the salubrity of particular regions, and the health of their inhabitants, may afford like themes of illustration.

4. Note the relation of geological principles with the art of mining in any district with which you may be acquainted.

5. Seek either in the works of Phillips, Murchison, or other authorities, or from your own experience, or that of friends, examples of the successful or unsuccessful search for coal.

6. Instance the advantage of an acquaintance with geology, as regards civil engineering, in the construction of canals, railways, and lines of common road.

7. Study its connexion with agriculture, in the three particulars here mentioned—improvement of soils, draining, and procuring supplies of water,—and note local instances of these relations.

8. Inspect the stone buildings in your neighbourhood, especially those of ancient date; observe, with particular attention, their north and north-western sides, and the comparative resistance which these have offered to the action of weathering. Remark if the stones be placed in the horizontal position which they occupied in the quarry, like a book placed on its side; or if their

position be vertical, like a volume placed on its end; and if the latter, observe if the laminæ, or thin flakes of the stone, have not peeled off, and the stone decayed in consequence. Ascertain the quarries from which the material has been obtained, and the geological formation or group to which such localities appertain.

9. Collect the examples, which are numerous, in the history of the art, of statues, busts, &c., injured by the bad quality of the material.

10. The practice of transferring to a common-place book any facts of general interest, will speedily enable the student to form a copious and highly valuable store of information.

CHAPTER II.

SKETCH OF THE HISTORY OF THE SCIENCE—LOST WORK OF THEOPHRASTUS ON FOSSIL SHELLS—STRABO—SYSTEM OF PYTHAGORAS—LIVY—ERRORS AND SUPERSTITIONS—REVIVAL OF THE PURSUITS OF SCIENCE WITH THOSE OF LETTERS—BOCCACIO—LEONARDO DA VINCI—FRACASTORO—CONRAD GESSNER—AGRICOLA—PALISSY—NICOLAUS STENSON, OR STENO—VALLISNERI—MORO—SOLDANI—SWEDENBURG—HOOKE—WOODWARD—RAY—LEIBNITZ—LEHMAN—WERNER—DR. TOULMIN—DR. HUTTON—WILLIAM SMITH—THE GEOLOGICAL SOCIETY—THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

In offering a brief outline of the progress of this study, we shall pass over the generally extravagant representations of the ancient Oriental writers; though it is highly probable that some of their opinions, particularly those of the exceeding antiquity of our planet, which are ever favourite ideas with these authors, have originated, not merely in the exuberance of Eastern fancy, but have been suggested by an examination of the physical structure of our globe.

We find in the works of several of the most distinguished philosophers and poets of classic antiquity, frequent allusion to the phenomena of geology, and the occurrence of fossil organic remains. These remarks, however, are usually introduced with the view of illustrating other objects, and are seldom discussed as independent questions. In the destruction of ancient letters, the greatest loss which we have sustained, in this department of knowledge, probably consists in that of many of the works of Theophrastus, the writer on natural history, who, we are informed, wrote two books

on fossil shells; a subject which could scarcely have failed to lead him into discussions as to their nature and origin, and the agencies by which they had been deposited and preserved. These writings are supposed to have been known to Pliny, and to have afforded him some information in that part of his history in which the Roman naturalist treats of fossil remains. Herodotus* mentions the occurrence of petrified shells in the mountains of Egypt, with the view to prove that that country was once a gulf of the sea.

Xenophanes, a Greek philosopher, a native of Colophon, in Ionia, and founder of the Eleatic sect in Sicily, who flourished 535 B. C., among a variety of puerilities and absurdities, promulgated some speculations which subsequent experience has proved to be correct. He contended for the antiquity of the earth, the vital origin of the shells which it entombs, and inferred from their occurrence the previous submergence of the rocks beneath the waters of the sea.

Aristotle had learned from preceding observers many events which had occurred in the history of our globe, and has added some valuable observations of his own. From these he inferred, with singular accuracy, the nature of some of the most important geological agencies; and the filling up of rivers, the formation of deltas, the elevation of certain regions by volcanic agency, the conversion of land to sea, and of sea to land, and the universal law of change, were phenomena with which he was fully and philosophically acquainted. Strabo affords evidence in his writings† of having made still

* Book ii. sec. 12.

† See his Geography, book ii. chap. 3.

farther advances, commensurate with the more modern date at which he lived, and the progressive character of investigations of this nature. In discussing the chief problem of ancient times, the occurrence of fossil shells at great elevations and remote distances from the sea, he mentions, among others, an explanation (that of Xanthus the Lydian) which so naturally presents itself to the mind as yet untutored by science, that it is adopted by many who have not directed their attention to geology at the present day, which is, that the phenomena in question is occasioned by the diminution and retirement of the sea, in a manner analogous to the drying up of rivers, lakes, and wells in seasons of drought. The philosophic geographer, however, repels this, with similar hypotheses, such as that of Strato the naturalist, of seas having burst their barriers and formed new channels, and offers in explanation a theory which, in substance, has been adopted by modern philosophers, and proved by indisputable evidence to be correct. He boldly asserts that the cause is to be sought, not in changes of the sea, but of the land. After stating the extreme probability of a considerable portion of the existing continents having been successively sunk beneath and raised above the level of the ocean, he adds, "The same land is sometimes raised up, and sometimes depressed, and the sea also is simultaneously elevated and lowered. It results, therefore, that we must ascribe the cause to the ground, either to that portion which is under the sea, or to that which is inundated by it; but rather to that which lies under the sea, from its being rendered by moisture more moveable and susceptible of greater change." He continues,

"The real cause, I repeat, of all these changes is, that the bed of the sea is sometimes accidentally elevated, and sometimes depressed."

He subsequently enforces the necessity of consulting the existing phenomena of nature, with the view to explain the past, "such," he observes, "as are daily occurring to our observation—the deluges, earthquakes, and elevations or depressions of the bed of the sea; these are the causes of the rise or lowering of the waters." He adds, that as experience shows that not only small islets, but islands, and even parts of continents, are raised from the deep, so they may again be engulfed beneath the ocean.

It is highly interesting thus to ascertain that the doctrine of modern causes, far from being a recent discovery, is invested with the sanction of very high antiquity. We may also observe one, among the numerous instances afforded by the history of scientific research, of some original observer or profound thinker effecting discoveries which are not only in advance of past, but even of his own and succeeding ages. His opinions, imperfectly understood and appreciated by his contemporaries, are neglected, perhaps derided, and for a period forgotten: Time, however, the great revealer of truth, renders justice to his discoveries, and his merits and his opinions are rescued from the censure or oblivion of his own age, to be honoured with the late but enduring homage of posterity. Thus Strabo was unquestionably acquainted with the nature and results of elevating causes. Leibnitz assumed the original nebular condition of the solar system, and the incandescence and subsequent refrigeration of our planet,—a theory which the discoveries of later philoso-

phers have only tended to confirm. Linnæus, a century since, declared the calcareous rocks to be chiefly formed of organic substances,—an assertion which the investigations of the microscope have proved to be substantially correct. Dr. Toulmin, though doubted and disbelieved in his own day, has expressed opinions which contain the substance of the system of Dr. Hutton and the principles of Mr. Lyell; and the theory of Hutton himself, ill-understood in his own time, has become, by the eloquent illustrations of a Playfair, and the admirable expositions of a Lyell, better understood and appreciated, half a century after its publication, than when it was first announced to the world. To resume: Lucretius, the contemporary of Julius Cæsar, in his poem *De Naturâ Rerum*,* among a mass of unfounded theories and vague speculations, states several facts of truth and importance. He attributes the formation of the earth, the seas, and the atmosphere to the union of elementary atoms, impelled by the laws of affinity; and though destitute of any positive acquaintance with palæontology or botany, he says, that before men and existing objects lived, the earth had produced beings of extraordinary form, and vegetables of enormous size.

Ovid, in the celebrated passage of the 15th book of his Metamorphoses, while illustrating the system of Pythagoras and explaining the law of universal change, which constitutes the essence of the doctrines of that philosopher, affords proof of acquaintance with geological phenomena of considerable interest and importance, comprising, in fact, a summary of almost all the causes now in operation on the earth. They are so lucidly stated, and so ably explained by

* Book v.

Mr. Lyell,* that the reader is referred to his excellent work for more complete details, a selection of the most important being sufficient for the purpose of the present volume. Among the most striking are—

The conversion of land to sea, and sea to dry land.

The occurrence of marine shells at a distance from the ocean.

The excavation of level plains into valleys, and the destruction of hills, and removal of their detritus into the sea.

The change of marshes into dry ground, and of dry ground to stagnant pools.

The issuing of springs during earthquakes, and the drying up of others.

The desertion of their ancient beds by rivers, and their reappearance in new channels.

The uniting islands with main-lands by the growth of deltas and new deposits.

The insulation of peninsulas by the destruction of the isthmus which previously connected them with the main-land.

The submergence of land by earthquakes, and the phenomenon of cities appearing beneath a lake.

The elevation of plains into hills.

The petrifying power of certain streams, which convert the substances immersed in them to marble.

The shifting the site of volcanic action. "There was a time," says the poet, "when Etna was not a burning mountain, and a time will arrive when it will cease to burn!"

This celebrated description has attracted much

* See the Introduction to his Principles of Geology.

attention, and the following lines, which commence it, have been quoted in almost every introductory work on geology.

> "Vidi ego quod fuerat quondam solidissima tellus,
> Esse fretum, vidi factas ex æquore terras.
> Et procul a pelago conchæ jacuere marinæ,
> Et vetus inventa est in montibus anchora summis,
> Quodque fuit campus, vallem decursus aquarum
> Fecit, et eluvie mons est deductus in æquor."

The truth of the whole narrative will be generally acknowledged, with the exception possibly of the anchor found on the summit of the hills, which may be regarded as a mere poetic fable; like the beautiful but imaginary narrative of the destruction of the phœnix by fire, and its resuscitation from its ashes; or the explanation of volcanic agency, by the assumption that the earth is an animal, and that its mines of sulphur, taking fire, consume its internal unctuous substances, till these being exhausted, the flames die out for want of animal fuel! The last line, explaining the disintegration of mountain-masses, and their transport to the bed of the ocean by aqueous agency, has been noticed by Mr. Lyell as somewhat obscure. May it be permitted to suppose a slight corruption of the text to have taken place, and to suggest the requisite emendation? The mere change of two letters, by substituting "alluvie" for "eluvie," will render this description of alluvial action perfectly clear and satisfactory. The mistake is one which might easily have been committed by a transcriber, and which, in the then imperfect state of natural science, might have passed unnoticed.

Justin, to whom we owe the preservation of several curious passages of Trogus Pompeius, seems to adopt

the sentiment of that historian as to the igneous origin of our planet. He is of opinion, that the refrigeration having taken place at the poles, the Scythians must have been the first inhabitants of the earth! Livy has occasional notices of natural phenomena, disfigured, however, by his prevailing superstition. He informs us,* for instance, that at the period immediately preceding the death of Hannibal, fearful prodigies occurred. It rained blood, he states, for three days in the court of the Temple of Concord, and a new island rose out of the sea opposite to the coast of Sicily. The former phenomenon is ascertained to have been occasioned by an insect, a butterfly of the genus *vanessa*, which, on emerging from its *pupa* state, is known to emit drops of red liquor, so that a swarm of these creatures would naturally produce a shower resembling one of blood. A circumstance of like nature which occurred at Aix, in France, in the year 1608, occasioned similar alarms, which were dispelled by the celebrated Peiresc, who had paid considerable attention to entomology, and the transformation of insects. The apparition of the new island has its analogy in the elevation of the volcanic isle of the Mediterranean, which rose from the deep, a few years since, and shortly after sank again beneath the waters. These natural occurrences, however, which modern science can thus easily explain, so terrified the superstitious Romans, as to induce them to decree a supplication of the whole people, to the altars and temples of the gods, to avert the calamities which it was feared such prodigies portended.

The occurrence of fossil shells at a distance from the sea is noticed by several of the fathers, and in par-

* Book xxxix. c. 6.

ticular by St. Augustin and by Tertullian, who adduce them in proof of the deluge.

The knowledge of the subject possessed by the ancients, of whatever value or interest it may have been, was entirely lost during the benighted ages which succeeded, when the darkest ignorance prevailed respecting our earth; and the monuments of its physical history were associated with tales of the grossest and wildest nature.

It may, perhaps, be permitted in a work such as the present, devoted to the use of the tyro and the young, to enumerate a few of the legends which referred the phenomena of nature to the superstition of the times. There is, in fact, scarcely a single fossil object, which is not in some way mixed up with absurdities of this nature. Thus Pliny relates, that the tubular pointed shell *dentalium* was supposed, if used as a toothpick, to afford an infallible remedy for the toothache. The ammonite shells were believed to be so many petrified snakes, and the history and mystery of their fate was conceived to be that, as they abounded in the vicinity of Whitby in Yorkshire, near the abode of St. Hilda, a female devotee of extraordinary piety and influence, and as they constituted a very considerable annoyance, the inhabitants requested the saint to use her efforts, that the nuisance might be abated, and the snakes destroyed, with which prayer the lady graciously complied, by first praying their heads off, and then praying them into stone! The legend is recorded in the poetry of Scott.

> "And how the nuns of Whitby told,
> How of countless snakes, each one
> Was changed into a coil of stone—
> When holy Hilda prayed,
> Themselves within their sacred bound,
> Their stony folds had often found."
>
> MARMION, CANTO II.

To so late a period did this superstition prevail, that the author of a modern scientific work,* relates the instance of a dealer, who having been requested by his customers to supply them with some of the creatures which had escaped decapitation, and to procure some snakes with their heads on; and being actuated by the natural desire to gratify his patrons, and dispose of his wares, contrived to manufacture some heads of plaster of Paris, and affix them to the specimens; and thus pursued a thriving trade, till some remorseless geologist, who visited the place, not only beheaded the reptiles at once, but showed that they were in reality no other than fossil shells; thus annihilating the snakes, and a profitable branch of business together. They are now manufactured at Whitby by filing the extremity of the last whorl into the shape of a snake's head, and the accompanying illustration is from a specimen recently procured from that place.

FIG. 2.

Another legend, referring in like manner to a familiar fossil object, is also mentioned in the above-named

* Sowerby, Mineral Conchology, v. ii. p. 9.

poem. The fragments of the stems of *crinoidea* so commonly found in the older deposits, being hollow, were frequently strung and used as rosaries in the middle ages; they were called St. Cuthbert's beads, and are thus mentioned—

> "Nor did St. Cuthbert's daughters fail
> To vie with them in holy tale
> * * * *
> On a rock by Lindisfarn,
> St. Cuthbert sits and toils to frame
> The sea-born beads, that bear his name."
>
> MARMION, CANTO I.

These fossils bore, in Germany, the several names of *spangensteine* or bead-stones; *roeder-steine* or wheel-stones; *Bonifacius-pfennige* or St. Boniface's-pennies, being found in great numbers on a mountain near Ganserode in the neighbourhood of Frankenhausen, which mountain obtains its name from that saint; while in Westphalia they are called *hünenthränen*, from being considered the petrified tears of the giants. They are also variously termed millstones, cheesestones, basketstones, caskstones, &c., from their presumed resemblance to those objects.

The echinites were severally termed *ombria* from the Greek word ομβρος, signifying the heavy rain in which they were supposed to fall; *brontia* from βροντη, the thunder in which they were also believed to be thrown to the earth; *ceraunii lapides*, from κεραυνος, the lightning by which they were presumed to be generated and formed in the air; *chelonites*, from the resemblance in their sutures to the shells of the tortoise, and *ova anguinum*, from having been considered by some as the eggs of serpents.

Various virtues and supernatural powers were attributed to different minerals and fossil remains; they were worn as amulets and relics, and an especial value was assigned to the mineral *harmotome*, or cross-stone, on account of the sacred emblem of which it was conceived to be the type. Pliny relates that the Ethiopians attached great sanctity and value to ammonites, whether converted to stone or iron pyrites; they are still venerated in like manner by the Hindoos. The *nummulite* was the subject of many a German legend under the name of the *bauern-pfennige*, or peasant's penny, and *teufelsgeld*, or devil's money, under which appellation it was equally known. In certain parts of Spain, as recently as 1835, many individuals wore the *terebratulæ* shells in their pockets, as an infallible specific against cholera! The petrified teeth of sharks were alike conceived to act as a charm against various maladies. Under the name of *glossopetræ* they were believed to be the tongues of serpents or birds. At Malta they were supposed to be those of vipers petrified by St. Paul, while at Krain in Germany they bore the name of *teufelsklauen*, from an idea there entertained, that the evil spirit had torn his claws in the clefts and crevices of the mountain. The list of delusions may perhaps be closed with the fact, that the occurrence of the relics of the elephant and mastodon in superficial deposits, and the casual resemblance of the teeth of the latter animal to those of the human species, have unquestionably given rise to the fables which prevail in the mythology of all nations, of the existence of certain giants, who, having warred against the gods, were overcome by their celestial opponents, and crushed beneath the rocks. The most recent imposture, as regards this kind of organic re-

mains, is, perhaps, that of the skeleton which, in the reign of Louis XIII. was pretended to be that of Teutobochus, king of the Cimbri, who fought against Marius. The following are the circumstances which gave rise to the tale.

On the 11th of January, 1613, in a sandpit near the Château de Chaumon, between the towns of Montricoux, Serras, and St. Antoine, some bones were found, several of which were broken by the workmen. A surgeon of Beaurepaire, named Mazurier, informed of this discovery, possessed himself of the bones, and contrived to turn them to good account. He gave out that he had found them in a sepulchre, thirty feet in length, upon which were inscribed the words *Teutobochus Rex.* He added that, at the same time, he found fifty medals bearing the head of Marius. He published these stories in a pamphlet, by means of which the curiosity of the public being aroused, he exhibited, for money, the bones of the pretended giant at Paris and other cities. Gassendi mentions a Jesuit of Tournon, as the author of the pamphlet, and proves that the pretended antique medals were fabricated, their inscriptions being in Gothic letters instead of Roman:—as for the bones, after having been exhibited as above-mentioned, they were put by in a chest at Bordeaux, and it was not till after the lapse of two centuries, in destroying a theatre, *la salle de Moliere*, a few years since, in that city, that these royal remains were re-discovered, when they were recognised to be those of a mastodon. The list of works cited by Cuvier as having been written during this controversy is extremely long and curious.

A singular superstition grew up in Germany, under the following circumstances. The miners, who, in that,

as in every other country, are an extremely superstitious race, ascertaining that the occurrence of cobalt was unfavourable to their success, since when that substance was found, metallic ores were rarely to be discovered, conceived such a horror of this mineral, that they regarded it as an actual demon. *Der Kobbold,* as he is termed, was the theme of many a legend and song; he figures as an actual personage in a highly imaginative drama, drawn by the heroic and gifted Körner, *Die Bergknappen;* and at an earlier period it was customary, in the mining districts, to put up prayers in the churches, for the protection of the miners against this foe to their hopes and success!

The form and appearance of many limestones and sandstones, which have been occasioned by the impression of some organic substance, in some instances, of a large bivalve, have given rise to various well-known legends of petrified vegetables and fruits, as peas, melons, and loaves of bread. The German Professor Bruckman enumerates a long list of these petrified loaves, which he states are preserved in various places, as the church of St. Peter at Leyden, at Schemnitz in Hungary, and elsewhere, the tale connected with them being, that some rich but hard-hearted person having refused a loaf to the poor, it was immediately converted into stone, and the Professor concludes his enumeration of these wonders with the appropriate ejaculation, "*Da nobis panem, Domine, in diebus nostris; non durum et lapideum sed frugalem et sufficientem:* Give us bread in our time; not hard and stony, but such as is nutritious and sufficient for our wants."

But an Irish legend on the subject, which was communicated to the author by a friend, at the close of a

lecture, is, like all Irish stories, the most racy and characteristic, perhaps, of all the narratives extant on this theme. " Sure, now," said the informant, " ye've not hard of our Irish laygend of St. Pathrick's loaves. Well, I'll be telling it to ye. St. Pathrick was walking one day along the road, and 'twas very tired, he was, and very hungry, poor man! when he meets a stranger bringing a sack of loaves from the baker's. ' Good morning to yourself,' says St. Pathrick, spakin um civil. ' Same to you, Sir,' was the reply, ' wid all my heart and soul.' ' May be ye wouldn't be giving me one o' thim loaves ye're carrin,' says the saint, ' for its meeself that's just dyin wid hunger.' ' May be I would,' says the t'other, ' but its not loaves they are,' says he, ' its stones they are, entirely!' ' Well, thin,' says St. Pathrick, ' if they be stones,' said he, ' I'd wish they'd be turned to loaves,' says he; ' and if they be loaves,' said he, ' I'd wish they'd be turned to stones!' And wid that the sack fell down in the road, enough to break the man's back, for it was loaves they were and not stones, but by the powers of St. Pathrick they were changed into stones, and they're called St. Pathrick's loaves all over Ireland at the prisent day!"

Persons connected with museums and public collections are often subjected to very considerable importunity, and occasionally to very ill-judged censure, in consequence of their declining to accept or to purchase objects so familiar as ammonites, elephants' teeth, &c.; respecting which the mistaken proprietors have conceived the most extravagant notions, and of which it is impossible to dispossess them, they considering these well-known specimens to be in the one instance fossil snakes, and in the other fossil cauliflowers, or other plants.

The catalogue of absurdities of this nature might be largely increased; and there is scarcely a district, the organic remains discovered in which have not given rise to similar absurdities or impostures. Yet while we smile at the errors and superstitions of the vulgar, we shall find "the follies of the wise" and the absurdities of philosophers to be no less deserving of ridicule. Voltaire entertained a strong dislike to the geologists of his day, because they sought to prove the universality of the deluge and other events recorded in Scripture, by referring to the phenomena of nature, as affording evidence of their reality; hence he was so eager to deny the facts which they adduced, that he declared the *pectens* found in the mountains of Italy to be no fossils, but merely the scallop-shells which had fallen from the hats of the pilgrims on their way to the Holy Land!

The celebrated naturalist Scheuchzer, who with very considerable talents and attainments, possessed at least an equal share of credulity,—as was amply evinced by his conceiving the fossil plants of the coal formation to belong to existing types of vegetation, and fancying them to be ears of corn, flowers, pine-apples, &c.,—wrote, as is well known, a treatise on a fossil skeleton, under the title of "*Homo diluvii testis et theoscopos,*" the object of which was to prove the remains in question to be those of an individual who had been destroyed by the deluge; but which the more accurate Cuvier decided to belong to a salamander, of extinct species and enormous size. A similar specimen is placed in the British Museum, (Mineral Gallery, Room III., case 1.) The accompanying illustration depicts the subject of Scheuchzer's treatise.

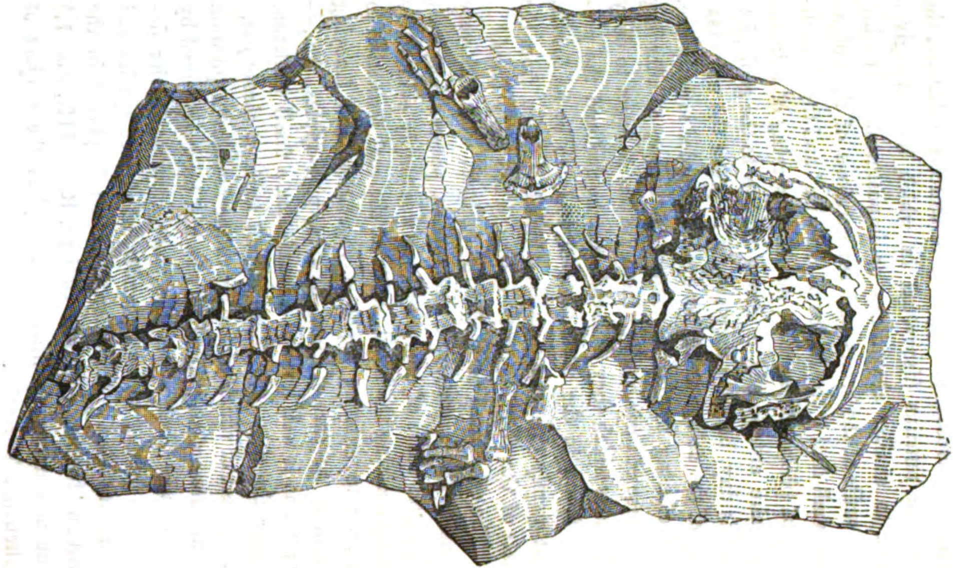


FIG. 3.—HOMO DILUVII TESTIS, OF SCHEUCHZER.

A work was also published in this country about fifteen years ago, the professed object of which was to prove that the teeth and bones of elephants and mastodons, discovered so abundantly in the superficial deposits, were not those of extinct races, but merely of those animals which had been domesticated and employed in their wars, shows, and games, by various nations, European and Asiatic. This opinion had been previously entertained in Italy and Sicily, and rejected by the *savans* of those countries.

It may here be mentioned, that a singular mistake has prevailed in modern times, with regard to a work containing some admirable figures of fossil shells, from the tertiary deposits of our island. Mr. Gustavus Brander, one of the trustees of the British Museum, having formed a collection of the shells of the Hampshire Basin, which he presented to that establishment, applied to Dr. Solander, who at that time superintended its fossil department, by whom they were described and published, with some admirable engravings, under the title of *Fossilia Hantonensia; collecta et in Museo Britannico deposita a Gustavo Brander, F. R. S.*, &c. &c. Strange to say, though the above title mentions the shells as having been merely collected and deposited in the British Museum by Mr. Brander, and though in a Latin preface he expressly informs us, that he is indebted "to the learned and ingenious Dr. Solander" for the scientific description of these objects, yet Mr. Brander has constantly been stated, even in some of the most recent publications on the science, as the author of the descriptions in question. The work is valuable, not only for the beauty of the figures, which are admirably drawn and engraved, but from the circumstance, that Dr. Solander, who was a pupil of Linnæus, was the first, in

this country, to apply the generic and specific names of his distinguished instructor to the description of fossil shells.

To resume: on the fall of the Roman empire, the natural sciences were cultivated with some degree of success by the Orientals, but we have no evidence that they acquired any farther knowledge of the structure of the earth than was possessed by the Greeks and Romans, and their inquiries were checked by the Mahometan clergy, who dreaded that researches of this nature might inspire a distrust of the Koran. The Koran itself also, by forbidding the representation of animals and of man, deprived science of one of its most useful auxiliaries, the art of design.

It was not, as might naturally be supposed, until the revival of letters, about the commencement of the 16th century, that the phenomena of geology began to engage the attention of the nations of the West. Among the earliest inquirers into the subject, as Brocchi* informs us, are two, of whom letters and the arts may be justly proud; Boccaccio, born at Certaldo, a small town of Tuscany, must have been accustomed from his childhood to observe the immense assemblage of fossil shells, of which the hills of that region are so largely composed, that, as Targioni observes, they occasionally render the soil barren. In his romance of Filocopo, he takes occasion to mention them, and speaks of them with much emphasis, adducing them as proofs of the sea having once covered the land.

The celebrated painter, also, Leonardo da Vinci, who, in conformity with the practice of that time, united the avocations of an architect and civil engineer with that of an artist, and had thus become acquainted with the struc-

* See his Introductory Discourse to the Study of Fossil Conchology in Italy.

ture of the earth, and the phenomena of nature, eagerly took part in inquiries of this nature, and an opinion having been expressed that these objects owed their origin to the stars, this distinguished man denounced the opinion as absurd, and ridiculed the idea of such a cause being sufficient to produce the occurrence of different petrifactions in the same spot, as leaves, sea-weeds, and crustacea.

Fracastoro, a celebrated physician and naturalist of Verona, to whose honour a statue was erected in his native town after his decease, is next cited as taking a similarly enlightened part in the two grand disputes then prevailing. The first of these was, whether fossil shells belonged to animals which had lived and multiplied on the spot where these relics were found; a proposition, the affirmative of which he strongly maintained, ridiculing the idea of their having been occasioned by a certain plastic force, which, it was asserted, had power to fashion stones into organic forms. The second related to the question, whether these phenomena were caused by the deluge, a notion which he as strongly opposed, contending that the transient nature of this visitation, and the fluviatile character of its waters, were calculated merely to strew such objects over the face of the earth, but were quite insufficient to bury them in the strata of mountains, and at the depths in which they now lie entombed. Science, which had revived in Italy, soon diffused itself in other regions, and Germany, a country abounding in mines which presented admirable facilities for investigating the structure of the earth, produced philosophers, whose ardour and genius contributed in an important degree to the advancement of philosophical knowledge.

Conrad Gessner, who was born at Zurich, 1516, and died there of the plague in 1565, was one of the most learned and gifted men, not only of his own, but, it may be said, of all time. He is usually termed the Pliny of Germany; occasionally he is styled the Linnæus of his native land; and when we consider the comparative shortness of his life, the variety and extent of his attainments, and his proficiency in literature and philology, as well as in medical and natural science, we must acknowledge that while he resembled the immortal Swede, in the ardour and success of his inquiries, he may be said to claim the pre-eminence for the wider range of his inquiries, and the greater universality of his merits. His biography presents events of considerable interest: born of poor parents, his father being a furrier, he was assisted in completing his education, by his maternal uncle, Jean Frick, a minister, who perceived his dawning genius, and instructed him in literature and in botany as it was then known. But his uncle having died, and his father being killed in the battle of Zug, the youthful student saw himself compelled to seek his fortune abroad, and to finish his studies by the aid of charitable sympathy and private friendship. He was thus indebted to the kindness of the canons of Zurich, and to a young friend, a native of Bern, whose name, Jean Steiger, well deserves a record. In the pursuit of knowledge, he visited Strasburg, Paris, and Bourges, and returned to his native place to assume the duties of a schoolmaster; which occupation, however, he quitted for the practice of medicine. He subsequently became professor of Greek, at the university of Lausanne, obtained the degree of doctor of medicine at Bâle, and continued to practise as a physician at Zurich,

pursuing his scientific labours in conjunction with the exercise of his profession. Having devoted his attention to patients attacked with the plague, which then unhappily prevailed, he perceived the symptoms of the malady on his own person, and feeling the attack to be mortal, repaired to his cabinet to arrange his papers, and calmly to await, like a philosopher, the approach of death, which occurred on the fifth day of the malady, in the prime of his life and powers, in the forty-ninth year of his age. He left a widow, but no children; and the Gessners of his native city, who were so celebrated in the eighteenth century in letters and the arts, were descended from his uncle André, who was celebrated in Zurich, for having received thirty-six wounds, at the battle of Zug, for having lived as many years afterwards, and attained the highest posts in the city. The pursuits of Conrad Gessner were of the most varied and dissimilar kinds, and his eminence undisputed in all. His favourite studies were philology and literary history, together with the theory and practice of medicine, associated with the physical sciences as far as they were then known, comprising the study of botany, fossils, minerals, geology, and the structure of the earth. He was equally skilled in the arts, and drew the illustrations for his various works, with a fidelity and skill which have frequently been acknowledged and admired. His most important literary production is his *Bibliotheca Universalis*, or catalogue of all known authors in Latin, Greek, and Hebrew, a work of immense learning and labour; as well as his *Mithridates*, a philological performance, in which we find the Lord's Prayer in the twenty-two languages with which, like the monarch after whom his treatise is entitled, he was acquainted. He farther

edited a great number of classic authors, and we owe to him the first translation of Ælian. His most valued performance in natural history is his *Historia Animalium*, which may be regarded as the foundation of modern zoology; while, as a botanist, he was the first to arrange plants in the order of classes, genera, and species, and thus to raise this study to a system. His personal character was as amiable as his philosophical attainments were eminent; pious, and pure; gentle and unassuming, he was equally admired and beloved. Unambitious and modest, he sought neither preferment nor honour, yet he could not fail to attain both. He was ennobled by the German emperor, Ferdinand I., the year before his death, with the addition of armorial bearings, in commemoration of his studies and attainments, while science has associated his name with the productions of nature. The botanists of succeeding generations have consecrated a tulip, (*Tulipa Gesneriana*,) and an American shrub, (the *Gesneria*, a genus of the family of the *Campanulacæ*,) to the memory of so hallowed and revered a name! We may add, that when a descendant of his family studied medicine under Boerhaave, that philosopher, from respect to his memory, begged to be excused from taking the usual fee.

Agricola, who, in conformity with the usage of the time, latinized his German name of Bauer into the above appellation, by which only he is known in science, was born in 1494, at Gleuchen, in Misnia. He first studied at Leipzig and subsequently in Italy, under those *savans* who then rendered that land the country of science and letters. He next devoted himself to the practice of medicine at Joachimsthal in Bohemia: but his taste for the physical sciences, especially for metal-

lurgy and mineralogy, soon engaged his exclusive attention. He repaired to Chemnitz, the site of the rich mines of the electors of Saxony, descended into those subterranean excavations, and from sharing in the researches and labours of the workmen, acquired a complete knowledge of the theory and practice of mining operations. He was, however, too much in advance of his age to command its sympathy or assistance. It was in vain that he urged on the sovereigns of the country the importance of mining operations, and assured the dukes of Saxony, that the subterranean portion of their states was of higher value than its mere superficial surface. The remonstrances which he enforced were unheeded, and the assistance which he sought was withheld, yet he was by no means discouraged from pursuing his theoretical researches into science, and published a number of highly useful works on metallurgical, mineralogical, and geological science. He is considered to have been to these studies, what Conrad Gessner was to zoology, and to have been the first who directed the search after minerals and metals, on the principles of natural philosophy and the rules of enlightened theory. His most celebrated works are his treatise, "*De ortu et causis Subterraneorum*," and "*De re metallicâ*." His learning and attainments, though valuable in themselves and remarkable for his era, were insufficient, however, to free him from the prejudices of his age; and he continued a firm believer in the existence of gnomes and evil spirits, and their power to frustrate the efforts of the miner. He died in 1555, at Chemnitz, where he filled the posts of *Stadtphysicus*, which may be rendered Public Naturalist, and Burgomaster.

France boasts a distinguished philosopher of the same

era, in the celebrated Palissy, who was born in the diocese of Agen, in 1500, and is declared by his biographer, from his excellent qualities, to have been worthy the pen of a Plutarch. To this assertion we may add, that an instructive parallel, in the manner of that eloquent writer, might be drawn between this eminent man, who bears the title of the father of geology in France, and our own William Smith, who is honoured with a like designation in this country. Both were born of humble parents; both owed their education to their own efforts; and both achieved the most important discoveries by their own unassisted energy. Both were land-surveyors by profession; and both were induced by the natural talent and inclination of their minds, to study the structure of the earth, and look deeper than that mere surface, to which the studies of their vocation were confined. The philosopher of France, however, whose earlier lot fell on more "evil times, and evil men," than was the case with our English geologist, endured the calamity of religious persecution. He had early embraced the principles of the Reformation, and though highly honoured and patronized by the most eminent persons of the opposite faith, among whom were the royal family and the sovereign himself, their protection was insufficient to guard him from the persecuting spirit of the age. The Parliament of Bourdeaux having decreed, in 1562, the persecution of the Protestants, though the Duc de Montpensier gave him a safeguard, and declared his *atelier* a place exempt from violence, he was himself arrested, his *atelier* destroyed, by order of the judges of Saintes, the town in which he resided, and the interposition of the sovereign himself was requisite to claim him and preserve his life. He was summoned to

Paris, and lodged in the Tuileries, to which protection, like the celebrated Ambroise Paré, he, doubtless, owed his escape from the massacre of St. Bartholomew. He, subsequently, formed a cabinet of natural history and physical science, the first established in Paris; taught publicly; and, in his lectures, advocated various opinions which, then regarded as theories, have since been established as facts; among the chief of which are the formation of minerals, and the vital origin of fossils and shells, which were then regarded as mere *lusus naturæ;* but which he proved to be true shells deposited by the sea. Yet his merits and his services, however great and acknowledged, were insufficient to secure him a second time from persecution; he became obnoxious to the league, and was arrested, by order of the Sixteen, and confined in the Bastile. The reigning monarch, Henry III., went to visit him in prison, and finding him inflexible in his religious opinions, "My good man," said the king, "if you cannot accommodate matters on the point of religion, I am compelled to leave you in the hands of my enemies." The reply was worthy of a hero of antiquity, for, in fact, it was dictated by a higher enthusiasm and a holier courage,—"Sire," replied the venerable sage, "those who can compel *you* can have no power over *me;*—for I know how to die!" The Duc de Maine, though unable to effect his deliverance, found means to retard his trial: and he terminated in prison (1589,) a life which he had honoured by great talents and rare virtues. He was a man of remarkable genius and attainments, obtained considerable fame and reputation as a painter; and devoted fifteen years of painful toil and research, during which he endured the extremity of poverty and want,

to discovering a peculiar method of enamelling earthenware. On achieving his object, and perfecting his figures of this material, to which he gave the name of *rustiques figulines*, (from the Latin, *figulina*, pottery,) they were highly valued, and purchased by princes and potentates in his own time, and are now inestimably prized by collectors and virtuosi. It is, also, to Palissy that agriculture is indebted, for the discovery of the use of marl as a mineral manure.

To revert awhile to Italy; the progress of natural history in that country, during the corresponding period, may be estimated from the taste which arose towards the close of the sixteenth century, for forming and describing collections; pursuits which may be regarded as the most legitimate and instructive mode of studying the science. The richest collection, as we are informed by Brocchi, then existing in Italy, and perhaps in Europe, was that of the Vatican, formed under Pope Sixtus V., and arranged, described, and figured by Mercati, whose amount of philosophic knowledge may, however, be estimated by the fact, that he attributed fossils to the agency of the celestial bodies. The collection of the Vatican was dispersed soon after the death of Mercati, but others were formed at Verona, Naples, Milan, Bologna, and other cities of Italy, which soon led the way to more just and enlightened opinions. Thus Cesalpini, the botanist (1596,) may be mentioned as one of the earliest who determined the real nature of fossils, ascribing them, in distinct terms, to "the retiring of the sea and the lapidification of the soil." The distinguished Fabio Colonna, another botanist of eminence, (1626,) achieved a still farther progress, and showed not only the reality of shells, but ascribed them to dis-

tinct genera and species, proving that some were referable to marine, others to fresh-water kinds, and that the teeth found with the marine species were not those of serpents, as had been supposed, but of sharks. He farther points out the difference, first of the petrified shell itself; secondly, of the mere impression; and, thirdly, of the cast which the decomposition and disappearance of the shell have left on the substance which it has inclosed. Steno, as he is called by the Italians, but whose name in his native tongue is Nicolaus Stenson, a native of Copenhagen, naturalized in Italy, who flourished about the middle of the seventeenth century, was an able anatomist and physiologist, one of the earliest who observed and described, with accuracy, the muscular and nervous systems, and the structure and functions of the brain. He alike directed his inquiries to mineralogy and geology, and his work, the quaint Latin title of which, *De Solido intra Solidum contento*, may be translated, "A Treatise on Minerals and Fossils contained in solid Rocks," displayed many sound and philosophic principles, which, however, were mingled with several of the prevailing errors of the time, and in deference to existing prejudices, were rather submitted as propositions than affirmed as facts. He contended for the vital origin of fossil remains, but considered that they might have been produced by the Noachian deluge. He farther assumed, that fossil vegetables are the remains of once living plants, and that the mountains are of secondary origin, formed since the creation of the earth itself. He was a man of very powerful and gifted mind, highly improved by careful study and cultivation, and would, doubtless, have effected much more for science, had not his attention been called away

to other objects. Having been appointed by the Grand Duke of Tuscany, Cosmo III., tutor to his son Ferdinand, he was induced to embrace the Catholic faith, to quit the medical, for the ecclesiastical profession, and was thus led into various controversies with the ministers and professors of the reformed faith. Appointed a bishop (*in partibus*) by Pope Innocent X., he died, after various changes of abode, at Schwerin, 1687. His remains, at the request of the Grand Duke, were removed to Florence, and there interred.

Scilla, a Sicilian painter, published, in 1670, a work on the fossils of Calabria, in which he vindicated the vital origin of these objects, ascribing them, possibly more from a wish to conciliate opposition, and avoid interference with the prejudices of the age, than from any real conviction, to the agency of the deluge. Quirini, however, (1690) in a work descriptive of fossil shells, expresses opinions far more liberal and advanced; maintains that petrified shells cannot have originated from the deluge recorded by Moses; intimates that the scriptural relation of this event is not to be subjected to a strictly literal interpretation, and suggests, among other propositions, the idea that the visitation in question was by no means universal in its prevalence. In support of these positions, he denies that bodies of such considerable weight could possibly have been floated to the summits of lofty mountains, or that the agitation of the waves could have produced such a result; citing the statement of Boyle, then recently published, that the most furious storms affect the sea only to a moderate depth. He is still less inclined to the doctrine of the shells having grown in the waters of the deluge, on account of the brief duration of that event, and the fact

that the excessive rains must have deprived the sea of its saltness. He states his own opinion of fossil shells to be, that as earthy particles combine in the sea to form the shells of mollusca, the same crystallizing process might prevail on land, and that the germs both of shells and fish might have been disseminated in the substance of rocks, and there have been developed by means of humidity. It has been observed that such an opinion, however absurd, yet inasmuch as it contradicts the previous fallacies of the plastic power of the earth itself, of the influence of the celestial bodies, and other chimerical agents, forms a step in advance towards the discovery of the truth.

Vallisneri (1721) was distinguished for the philosophic freedom of his doctrines, contending against the universality of the deluge and the adequacy of such a cause to account for the existence of fossils. Moro (1740) advocated the efficacy of igneous causes, and demonstrated the elevation of mountains, and the occurrence of other phenomena, to have been caused by their agency; while at the same time he strenuously contended for the literal interpretation of the six days recorded in the Mosaic account as the period of creation, commencing first with the prevalence of water, and next of animals and plants. His system bears some resemblance to that subsequently promulgated by Hutton, for which it may have furnished some ideas; and Mr. Lyell has admirably observed, that as, from the prolixity of his style and the novelty of his views, he required an expositor, the Scottish philosopher was not more fortunate in the advocacy of Professor Playfair, than was Moro in that of his admirer Generelli, who, nine years after, delivered to the assembled Acade-

micians of Cremona a spirited exposition of his theory. It may be stated as a farther and singular coincidence, that as we owe to Professor Playfair, in later times, the idea of a destructive and conservative power in nature, which form a counterbalance to each other; Generelli concludes with enforcing the same principle, and contends that Providence has constantly raised from the deep, fresh mountains to supply the destruction or disintegration of others,—a fact, he adds, which fully and satisfactorily accounts for the number of crustacea and other marine objects now found in many mountains.

Marsilli (1740) showed the very important truth that fossil shells are not distributed at random, but in regular orders of families,—a fact which, somewhat later, (1750) was more fully and completely established by Donati. Targioni (1754) proved that the elephants whose remains were abundantly discovered in various parts of Italy, once existed on the strata from which their relics are exhumed; while Arduino (1759) made the important advance of classifying the rocks into primary, secondary, and tertiary deposits.

Baldasari (1767) in a memoir on a fossil jaw-bone (that of a mastodon) enters into many philosophical speculations, and establishes several important principles of geology. One is, that the sea has certainly had a permanent abode on our continents,—a doctrine which he founds on the three convincing facts, of the regular distribution of marine objects in the strata of mountains, on the natural position presented by corals and polyparia, and on the circumstance that the calcareous strata are perforated by *pholades*. He inculcated, almost in the same words, the excellent principle which, Mr. Lyell informs us, was adopted by the early mem-

bers of the Geological Society, that it was necessary to collect materials before forming systems; and states that it is with this view that he calls attention to the fossil jaw in question, which was procured from Monte Pullonico, in the territory of Sienna, and which he correctly refers to those described by Guettard, as having been discovered in America and India, and which are now recognized as those of the mastodon.

Soldani (1789) is alike celebrated for the comprehensive nature of his inquiries, and the philosophic accuracy of his decisions. While he devoted especial attention to microscopic investigation, and published a splendid work on the minute zoophytes and shells, he formed the most enlarged views of nature; devoted his researches to the structure of the whole earth; and the action of water, the formation of mountains, and the composition of rocks were the objects of his patient studies and his enlightened publications. It may be cited as his highest eulogium, that he was too much in advance of his contemporaries to be esteemed or appreciated by them. His large work above-mentioned, published in 1789, was so coldly received by the public, that he was about to commit to the flames the greater part of the manuscript of the second volume, and actually consigned to the brazier the whole of the copper-plates. But his writings, though scarcely appreciated at home, were prized and studied abroad,—in Germany by Fischer and by Moll, and in France by Montfort; while his countryman, Professor Ricca, called attention to his merits and pronounced his public eulogy some years after his decease. Brocchi adds, that he is, even now, scarcely honoured in proportion to his deserts, and in particular, that having been the first to call attention to

the occurrence, in various parts of Italy, of fresh-water deposits among those of a marine origin, his admirable observations have been passed over in silence by later writers, to whom, however, they could not have been unknown.

The history of geological inquiry during the 16th and 17th centuries will be perceived to have consisted chiefly of a series of contests on these questions—the organic nature of fossil objects, and their deposition by the deluge; a kind of compromise being usually effected, and naturalists conceding what they considered the minor point, the universality and power of the flood, in order to secure what was regarded as a more important object, the animal origin of fossil remains. Towards the close of this period, Leibnitz, in his *Protogæa*, published those views of the original incandescence of our planet, and its subsequent refrigeration, which later inquiries have tended so largely to confirm. Another distinguished mathematician of the same era, Dr. Hooke, promulgated, in his writings, similarly just and enlightened views of the organic nature of fossils—the extinction of species,—the former tropical climate of the earth,—the effects of volcanic action, subterranean and submarine,—the elevation and depression of the land, &c., &c. The celebrated naturalist, Ray, had already lent the weight of his character and attainments to this new but progressive study; and Dr. Woodward subsequently farther promoted its cultivation by bequeathing his collection to the University of Cambridge, and endowing a professorship of the science. The naturalists of Italy, already mentioned, Vallisneri, Moro, Generelli, Donati, Targioni, and others, prosecuted its inquiries with energy and success, and Linnæus directed

his all-comprehensive investigations to the structure of the earth. He contends against the universality of the deluge; arranges the different formations in a natural order of succession; shows that the calcareous deposits are of vital origin, composed of zoophytes and shells, and proves that animal as well as vegetable remains have contributed to make up the solid crust of the earth. The distinguished Buffon contributed to the advancement of the science in France; and it may be considered a proof of the value and truth of his opinions, particularly those by which he declared that the existing continents are of later date than the earth itself, and are doomed to be destroyed before it, that he was compelled to relinquish them by the faculty of the Sorbonne. The countrymen of Leibnitz successfully prosecuted the same inquiries; and, in the year 1759, Lehman, director of the Prussian mines, a skilful mineralogist and chemist, the discoverer of magnesia and barytes, published a work, in which he classified the rocks into a primary, secondary, and tertiary division, in the same year that Arduino, an Italian naturalist, proposed, as before-mentioned, a similar arrangement.

The celebrated Emanuel Swedenburg, (1720,) in the early part of his career, acquired considerable proficiency in the physical sciences, traces of which are discernible in his later and more mystical writings. His publication entitled, *Opera Philosophica et Mineralogica*, in three volumes folio, with numerous engravings, was justly regarded as a most extraordinary performance. On its appearance, various learned bodies vied with each other in electing him a member of their respective societies; and the Academy of Sciences of Paris translated into the French language, for their *Histoire des Arts et Métiers*,

his Treatise on Iron from this work, as affording the most valuable authority on the subject then extant. His scientific observations, though alloyed with the mysticism and extravagance which pervade his writings, contain some sound principles and instructive facts; and the nebular theory of the solar system, the original fluidity of our planet, the various preparatory changes of the earth, as opposed to the prevailing idea of its instantaneous creation in its present matured condition; the succession of various tribes of animals; these, with other assertions the truth and accuracy of which have been demonstrated by modern science, are the lights which shine through the misty maze of superstition and absurdity of which his productions so largely consist. It may incidentally be noticed, that the writings of this extraordinary man evince that he was also acquainted with phrenology.

Werner, who succeeded to the professorship of mineralogy at Freyberg, in Saxony, in 1775, directed his views from that science to geology, and the general structure of the earth; and, by his genius and eloquence, obtained for a lengthened period universal favour and popularity for his opinions, though they are now considered erroneous, and even at the period of their publication were recognized as being derived rather from the labours of his predecessors, than from any extensive or original researches of his own. As the summary of his system, it may be stated, that water was considered the universal agent in the formation of rocks, which, from the granite up to the most recent beds, were all regarded as aqueous deposits; while volcanoes, which in modern times constitute so important a cause in their production, were conceived to be merely of recent date,

and to have been quite unknown and inoperative in the ancient history of the earth. From the powerful and universal agency thus ascribed to water, his followers were termed Neptunists; while their opponents, who advocated the igneous origin of many rocks, and maintained the action of fire, were termed Vulcanists; and as certain theological views were most unaccountably and absurdly mixed up with this purely scientific question,—the partizans of Werner being, without any sound reason, regarded as the champions of orthodoxy, while their antagonists were, as unjustifiably, looked on as innovators and heretics,—this philosophical dispute was often conducted with the most unphilosophical bitterness and asperity.

The great faults of Werner and his system, the dogmas of the universal operation of water, and the utter exclusion of an agent so obvious as fire, have long since been exploded, as the mistakes and weaknesses of an early state of the science, which more mature investigations have sufficed to correct. His errors, both of theory and practice, are to be ascribed, as is usually the case, to the position of the man, and the prejudices which that position induced. As a mineralogist, he was led, by his peculiar bias for classification, to apply a strict and contracted method of arrangement to phenomena, too vast and varied for so narrow a limitation; and, in practice, he formed his conclusions as to the structure of the whole earth, from the partial investigation of a single district. Hence, his system has met with the fate of all those, the tendency of which has been to form extensive generalizations on few and insufficient data, and to determine the vast and universal operations of nature from observations of

local extent and limited influence. He formed a world on the model of the valleys of Saxony, (even these being hastily and imperfectly investigated,) rejected the possibility of igneous rocks, when the inspection of a trap-dike would have convinced him of their reality; and denied the existence of ancient volcanoes, when a journey to Auvergne would have satisfied him of their existence. He was, however, a man of very high order of mind, gifted with genius, energy, and eloquence; while, as a mineralogist, he was eminently acute and skilled in power of classification and arrangement, as well as in determining the order and succession of local deposits. His very errors have served as a guide to later observers, who, warned by his example, first seek sufficient data before they presume to propose a theory, and visit the scene of inquiry ere they attempt to form a judgment as to the phenomena which it presents. When doubts were entertained as to the nature of basalt, Dr. Buckland, by a journey to the coast of Antrim, satisfied himself on the spot of its igneous origin. When rumours of the elevation of Sweden prevailed, Mr. Lyell, by two visits to that country, assured himself of the truth of these reports. And, at the present moment, our most eminent and active geologists, after having almost exhausted their native districts, seek in distant regions, in the deserts of Russia, or across the vast Atlantic for facts, by which to confirm their observations in British localities; or to establish fresh generalizations and extend, by new discoveries, the previous limits of the science.

Meanwhile De Saussure and Pallas had arrived at similar conclusions, by means of independent researches; the one by the exploration of Switzerland

and the Alps, and the other by that of Siberia and the Ural mountains, both recognising the existence of internal heat, and its operation in raising portions of the earth's surface into mountains.

To revert to native authors, we would call attention to a writer, whose opinions have not been mentioned either by Mr. Lyell, or Professor Whewell, though they certainly are highly deserving of notice. We allude to Dr. Toulmin, whose Essay on the Antiquity of the World was published about the year 1775. It affords an interesting example of the progress of public opinion, that sentiments which little more than half a century ago drew on their author the opprobrium of being a sceptic, are, at the present day, recognised by all the philosophers of the age, as by no means inharmonious with revelation. His opinions on some isolated geological facts are palpably erroneous; as when, for example, he conceives that the diminution of shadow cast by the mountain which overhangs the village of Castleton, in Derbyshire, is occasioned by a change in the axis of the earth, it being obviously caused by the gradual disintegration of the mountain itself; but the following, which are his general views, will be found not only to be correct in themselves, but to anticipate, to a considerable extent, the discoveries of later observers. He maintains that *no single substance in nature is either permanent or primary*; that the animals, the vegetables, the earths, the stones, the minerals alike take their origin in the gradual progress of time, and in its increasing succession are alike exposed to innumerable transmutations; that the globe itself, from a multitude of causes, is subject to the most slow, but interesting revolutions; that it under-

goes incredible changes from heat and cold, volcanoes and earthquakes; that vast alterations are perpetually made by the decay, generation, petrifaction, and other transmutations of vegetables and animals; that the sea is continually altering the very face of the earth; that in the lapse of time, it alternately encroaches on the dry land, takes it from its inhabitants, and restores it to them again; and that gradual but obvious influences occasion those numerous, but partial inundations which have been found to make such deep and lasting impressions, and have existed in every country, leaving behind them the most visible marks of ruin and devastation. The great conclusion of the author is, that *nature is invariably the same—her laws immutable and eternal.*

The whole of the above remarks are highly instructive and correct, while many of them will be found to convey the substance of the systems of later philosophers. The first passage, which we have distinguished by italics, contains the essence of the theory of Dr. Hutton; the second embodies some of the leading principles which, recently enforced by Mr. Lyell, were, at an earlier period, advocated by Dr. Hutton and Professor Playfair, and by the latter in language which would seem borrowed immediately from Dr. Toulmin himself. "Amid all the revolutions of the globe," observes the Professor, "the economy of nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts, but the laws which direct these changes, and the rules to which they are subject, have remained invariably the same."*

* Illustrations of the Huttonian Theory, § 37.

The most distinguished opponent of Werner in this country, or, we should rather say, the complete refuter and destroyer of his system, was the philosopher already named, Dr. Hutton, a Scottish physician, whose opinions, on all essential points, were the very reverse of those of the professor of Freyberg, substituting for the limited views of the teacher of mineralogy, the more extensive generalizations of the observer of universal nature; and, for data and decisions formed from one of the natural sciences, facts, and conclusions derived from nearly all.

As the substance of his theory, he taught the following important and deeply instructive truths, which there is some difficulty in expressing in a condensed form.

His first lesson is, that no geological phenomena afford any proof of the beginning of things.

Next, that the oldest rocks are merely derivative compounds of the ruins of rocks which existed before them, and which were destroyed, chiefly by the slow action of atmospheric causes; while their detritus, borne by rivers to the ocean, and loosely strewed over its bed, became consolidated by heat, and subsequently upheaved and fractured.

That the metamorphic rocks were originally sedimentary deposits, similar to the secondary, but that they have been altered by the long-continued action of heat.

That granite has crystallized from a state of igneous fusion, under conditions of heat and pressure. In other words, that it has been melted by fire, at great depths in the earth, and has cooled under pressure so vast as to have prevented the gaseous portions of its elements from escaping, and has thus assumed its present crystalline texture.

Such is an imperfect outline of the celebrated system of Dr. Hutton; which has not only supplanted that of Werner, but has formed the foundation of the researches and writings of our most enlightened observers, and is justly regarded as the basis of all sound geology at the present day.

If we examine the above propositions in detail, we shall only find them to have been confirmed by repeated investigation. The crystalline texture and igneous origin of granite admit of neither doubt nor dispute; the metamorphic character of the succeeding deposits, the gneiss and mica-schist systems is equally clear, whether we conceive with Mr. Lyell, that the metamorphism was complete, or with Professor Phillips,* that it was only partial. The remaining point, that of the derivative character of the aqueous deposits, is a fact, alike undisputed; and the whole of these propositions are only better understood, and more firmly established, after having stood the test of half a century of investigation.

The most important and novel of the whole, the altered character of the metamorphic rocks, is conceived to have been fully demonstrated in theory by Sir James Hall, who, by pounding chalk and hermetically sealing it, so as to prevent its gases from escaping, and then exposing it to heat, converted it into crystalline marble; the very result presumed to have occurred in nature, by the hypothesis of Dr. Hutton. In a practical point of view, the fluid nature of granite was considered to be proved by the investigations of the author himself, who discovered in Glen Tilt veins of granite, ramifying

* See his Treatise on Geology, in Lardner's Cyclopædia, vol. i. p. 109.

into superincumbent rocks, in a manner which could only have been effected by a substance in a melted state, a discovery which is said to have filled him with so much delight, that his guides, says his biographer, conceived that he must have discovered a mine of gold. His opinions are farther conceived to be demonstrated by the passage of these rocks into each other: by the graduation of plutonic into metamorphic deposits, and of the latter into others of decidedly aqueous origin; of granite into gneiss, and of chlorite-schist and mica-schist into clay-slate, a fact demonstrating the intimate relation of each, and the common origin of all, proving them in short to be what he declared them, sedimentary deposits, altered by heat under pressure.

Another individual, who has already been mentioned in these pages, unassisted by the advantages of wealth, station, or collegiate education, was, in the mean time, largely extending our knowledge, by a series of the most laborious, practical observations. William Smith, a surveyor, by dint of unwearied observation, and the natural powers of a mind unusually strong, had arrived at results, similar to those obtained about the same time by the most distinguished continental geologists, of the laws of superposition of the stratified rocks; having discovered, that the order of succession of the different groups was never inverted, and that they might be identified at very distant localities, by their characteristic fossils. From the period of publishing his Tabular View of the Strata, in 1790, he continued his labours, under every difficulty and discouragement. Unaided, unpatronized, almost unnoticed and unknown, he pursued, alone, and on foot, a series of investigations, which ter-

minated in the publication, in 1815, of his Geological Map of England, a lasting monument of native powers and unwearied perseverance, and to which D'Aubuisson, a distinguished pupil of Werner, paid a just tribute of praise, observing, that "what many celebrated mineralogists had only accomplished for a small part of Germany, during half a century, had been effected by a single individual for the whole of England."

The remaining events which mark the history of the science, as regards this country, may be comprised in a brief epitome. The casual assembling of some friends for the transaction of business of scientific import, occasioned the wish for the continuance of meetings which were found to be as instructive as they were delightful, and gave rise to the Geological Society, an event, which more than any other, has promoted the advance of the science. Warned, by example, of the danger and difficulty of hasty generalizations, and imperfect theories, its members wisely and carefully abstained, for a considerable period, from all attempts of this nature, and Mr. Lyell has recorded the intention and the eulogy of the society in the same sentence, by declaring the object of its supporters to have been to multiply and record observations, and patiently to await the result at some future period: while their favourite maxim was, that the time had not yet arrived for a general system of geology, but that all must be content, for many years, to be exclusively engaged in furnishing materials for future generalizations. A resolution thus judicious and prudent could not fail to produce the most satisfactory results, and the natural consequence has been, not merely to rescue geology from the suspicion

and distrust which once attached to it, but to render it the most favourite, as it unquestionably is the most fascinating, of all the physical sciences.

Similar societies were formed in the capitals and provinces of the British empire, and of France, Germany, Belgium, &c. Some few years since, the *savans* of Germany conceived the idea of holding annual meetings, for the purpose of scientific investigation, and under the unassuming title of *Naturforscher*, or Inquirers into Nature, of meeting and communicating the result of their labours and researches during the past year. The plan, like many a foreign invention, was eagerly adopted and rapidly improved in this country; the British Association for the Advancement of Science, was instituted some twelve years since, for a similar purpose; among its objects geological investigation has ever formed a principal feature; a considerable portion of its funds has been devoted to the assistance, not only of native, but of foreign inquirers, and the general interests of the science have been largely promoted and advanced by the aid of this Association.

We have purposely omitted to dwell on the labours of French *savans* in the same field, because they are too well known and appreciated in this country, and the discoveries and writings of Cuvier, of Brongniart, of Elie de Beaumont, of Dufresnoy and their associates, will form the subject of too frequent mention in the course of the following pages, to require any particular notice here.

To bring the history of the science down to the present moment, it may be necessary to advert both to the *acta* and *agenda* of its inquiries, and to mention both those questions and problems which are conceived to

be decided, and those which yet remain for determination. Among the former may be regarded the raising that group of rocks, named the old red sandstone, into the rank of a separate series, under the name of the Devonian system. For a considerable period, doubts had been entertained, as to whether the red sandstone occurring in Devonshire was identical with that of Herefordshire; the discrepancy between the two consisting chiefly in the fact, that the shells discovered in Devonshire are not found in Herefordshire, nor the fish of Hereford in the county of Devon. Mr. Murchison in his recent journey to Russia discovered both fish and shells in the same deposits: and the old red sandstone of Devon, Hereford, and Scotland, is now constituted a distinct series, under the title of the first of these various districts, as being the most abundant in organic remains.

The discovery, by Professor Owen, of new forms of reptiles, has widely extended the sphere of those types of animal life, and proved the age of reptiles to be no mere fancied epoch, as was once supposed, but a period which extended from the new red sandstone to the chalk; in other terms, through the vast cycles of ages, during which almost the whole of the secondary rocks were deposited.

Mr. Hopkins has recently applied, in a highly successful manner, the principles of mathematical investigation to the explanation of geological phenomena, particularly with reference to the dynamics of the science, the elevation of entire tracts of country, the prevalence of anticlinal lines, and the nature of transverse fissures, and fractures occurring at right angles to the central rise. He has thus brought a fresh and power-

ful auxiliary into the field of geological research, and has supplied a new link between mathematical and physical science.

The discovery of erect trees in the coal-formation, particularly of six splendid specimens found by Mr. Hawkshaw, on the line of the Bolton and Manchester Railway, together with the researches of Mr. Bowman, Mr. Logan, and others, has tended to modify, to a considerable extent, the opinions previously entertained as to the mode in which coal was deposited; and whereas it was formerly believed to have been generally distributed by drift, and but occasionally to have vegetated on the spot where it is now discovered, the reverse of this sentiment seems now to prevail, and the greater part of the coal is believed to have grown on or near the spot where it is now found, while the instances of drift, at all events, to any remote distance, are conceived to form the exception to this general rule. Certain coal-plants, moreover, the *sigillariæ*, which have hitherto been regarded as appertaining to the monocotyledonous class, are now considered as belonging, with more probability, to the dicotyledonous division; and as the genus is numerous, such an alteration would change, to a considerable extent, the relative proportion of the two orders of plants of this formation.

It may be added among the most recent advances in geological inquiry, that Mr. Murchison having some time since stated it to be his opinion that the Silurian deposits are the oldest fossiliferous rocks, recent researches have tended strongly to confirm this view, and to show that both the Cambrian and Cumbrian systems, which lie beneath, present so close an analogy, in many important points, with the Silurian, as to render it highly

probable that the whole will hereafter be regarded as one common series, that of the protozoic or earliest rocks which contain organic remains.

Erratic Blocks.—With reference to these phenomena, the large boulders and masses of primary rocks, which are found scattered over the superficial soil, in every country of the north of Europe, our own included, the weight of evidence unquestionably is in favour of the supposition, that they have been transported by masses of floating ice, which, on melting or separating, have dropped these blocks to the bottom of the then existing sea. On this point, among other proofs, the evidence of M. Durocher, now professor at Rennes, in Brittany, who has attentively studied these boulders as they occur in the north of Europe, may be regarded as conclusive. His sentiments are in substance as follows:—As the direction of the blocks is usually from north north-west, to south south-east, he conceives that in the first instance some powerful erosive agency has disintegrated and destroyed the mountains of the north, reducing their masses to blocks, which have accumulated at their feet on the coasts then in existence, while, at the same time, the rivers and streams have tranquilly conveyed the smaller detritus into the sea. During intense winters, masses of ice have embedded and floated away these blocks, thus lying on the coast; and such ice-bergs, on melting, have deposited the blocks in various directions. The elevation of the bed of the sea has subsequently brought them to light.

The Glacial Theory.—Among the *agenda* of the science, or the questions yet to be proved, or which may be considered as hitherto demonstrated only in

part, may be reckoned the glacial theory of M. Agassiz. This philosopher, having followed out the researches of Venetz, Charpentier, and others, and having arrived at the conclusion, that the glaciers of the Swiss Alps had formerly a greater extension, and reached as far as Mount Jura, determined to investigate the traces of their existence in England, Scotland, and Ireland. The existence of glaciers of far greater importance and extent than those existing at this moment, covering, in fact, the whole of Switzerland, and presenting an area of sixty leagues, with a surface of more than two hundred square leagues, seems to have been completely and satisfactorily established by the researches of M. Charpentier, whose testimony is of the more value, because having at first been opposed to the hypothesis, he became, by the result of his inquiries, a convert to the theory of which he was before the opponent. But though the existence of these vast fields of ice, in Switzerland and its vicinity, seems to be thus demonstrated in a convincing manner, it is by no means so clear that the same phenomena existed in other and distant regions; and even if they did prevail, it is not considered that they can account for the erratic blocks, which we have already referred to another cause. As the result of the investigations of M. Agassiz in this country, he conceives that the markings and striations of the rocks observed in these districts are similar to those occurring in Switzerland, and testify the former existence of extensive glaciers in these regions. He farther applies their agency in explanation of many local phenomena; in particular, of the erratic blocks, and of the parallel roads of Glenroy, which are certain level terraces on the sides of mountains, previously

supposed to be ancient sea-beaches left by the retiring of the sea. His views have been warmly espoused both by Dr. Buckland and Mr. Lyell, though they have met with much opposition in Germany,* and though it is admitted that they scarcely account in a satisfactory manner for all the phenomena which they are adduced to explain, in particular the parallel roads above-mentioned; while Mr. Murchison, on his recent visit to Russia, found them alike insufficient to explain the erratic blocks strewed over vast portions of that country.† The late Mr. Bowman, in a communication to the editor of the Philosophical Magazine, has stated the following objections to the conclusions formed in favour of the theory from the striated markings presented by the surface of the rocks. He states that he has found these marks to pervade the internal structure as well as the surface; and as they occur parallel to the plane of the magnetic meridian, he ascribes them to electro-magnetic agency, operating during the induration of the mass. Mr. Hopkins denounces the theory as contrary to every principle of mathematics and physics, in relation to the phenomena of several districts to which he has directed his researches; and finally, Dr. Buckland, in the published edition of his admirable Anniversary Address, (1841,) intimates that the opinions of Professor Agassiz and himself as the supporters, and of their antagonists the opponents of this hypothesis, will probably be modified into something like harmony of sentiment. These views are thus

* Particularly from Studer and Von Leonhard. See the admirable work of the latter, *Geologie oder Naturgeschichte der Erde, auf Allgemeine fässliche Weise abgehandelt*, p. 487, Stuttgart, 1840.

† See Proceedings of the Geological Society, vol. iii. p. 405.

expressed, in the usual felicitous style of this distinguished and philosophic observer.

"The contest will probably be settled, as in most cases of extreme opinions and exclusive theories, by a compromise ; the glacialist will probably abandon his universal covering of ice and snow, and be content with glaciers on the elevated regions of more southern latitudes than now allow of their formation ; the diluvialist, still retaining his floating icebergs as the most efficient agents in the transport of drift and erratic blocks to regions distant from their place of origin, may also allow to glaciers their due share in the formation of *moraines* and striated surfaces, in latitudes and at elevations that are no longer within the zones of perpetual congelation."

EXERCISES.

A subject so general as the history of a science affords little opportunity for exercises of a practical nature, while the brevity of our sketch renders recapitulation scarcely necessary.

The student may, however, transfer to his note-book, and otherwise impress on his memory, a few of the most important facts here adduced.

1. In perusing the history of the science he will observe, as might indeed naturally be expected, that the most philosophic minds are usually in the right, in opposition to the multitude; while, as we have before remarked, some great and gifted observer progresses not only in advance of past ages, but even of his own and those immediately succeeding. Thus, both Aristotle and

Strabo had formed far more just ideas of the phenomena of nature than were entertained by their contemporaries in general; Pythagoras, or rather the author of the system advocated as his, in the passage which we have cited from Ovid, has observed many facts of importance, and has rightly understood their nature. The opinions both of Boccaccio and Leonardo da Vinci were similarly in advance of their age, as were those of Leibnitz, Linnæus, Toulmin, and Hutton.

2. The progress of the truths of philosophy bears a striking analogy to the establishment of those of religion. The heresies of one period have frequently become articles of belief in that succeeding, and the martyrs of one age have been canonized or worshipped in the next; the admiration due from contemporaries has been paid by posterity, and the philosopher has been honoured and applauded only when he was alike beyond the reach of human censure or approbation.

3. The following may be regarded as the summary of the history of the science in modern times. The sketch will be sufficient to show that the progress of discovery has been most gradual and slow, and that every step in the march of philosophy has required to be obstinately contested and laboriously won. In the darker ages fossil remains were ascribed to the stars, or to some plastic power of the earth itself, or they were regarded as mere *lusus naturæ;* in fact, their origin was referred to every cause but that which was alone capable of producing them. It was only by long and arduous contests that naturalists succeeded in establishing the organic nature of these objects; and this point could only be gained at the price of conceding the universality of the deluge, and ascribing their occurrence to that

event. It soon, however, became evident that such a cause was inadequate to explain all the conditions under which these objects occurred: for instance, that though it might have strewn them over the surface, it never (as has been before mentioned) could have buried them in the strata of mountains, or entombed them deep within the earth itself. Again, it was observed that marine shells were associated in one spot, while the fresh-water kinds were collected in another, and that similar genera and species were in like manner separated and arranged, although it was obvious that the flood here contemplated must have heaped all kinds promiscuously together. And, when at length more extensive observation showed that the same locality exhibited alternations of marine and fresh-water deposits—in other terms, that it had evidently been the site of sea and land over and over again—it was felt that no single event was adequate to produce such varied effects; and hence arose those more extended and more satisfactory views of the operations of nature which constitute the principles of geology at the present day.

CHAPTER III.

FIRST LESSONS IN GEOLOGY—HARMONY OF THE SCIENCE WITH REVELATION—EXTREME ANTIQUITY OF THE EARTH—PROOFS OF THIS FACT DERIVED FROM THE STRUCTURE OF THE EARTH ITSELF—SIMILAR EVIDENCE AFFORDED BY ASTRONOMY—ORIGIN OF OUR PLANET—INTERNAL HEAT OF THE EARTH—CRUST OF THE EARTH—ORDER AND SUCCESSION OF THE ROCKS—TROPICAL CLIMATE OF THE ANCIENT EARTH—EFFICACY OF MODERN CAUSES.

We shall take the opportunity, before we enter on the more practical portion of our subject, to state some of those leading principles and elementary facts which will serve as an introduction to the science, and tend to facilitate the future progress of the student: these we shall term our First Lessons in Geology.

Harmony of the Science with Revelation.—Among the most valuable and most satisfactory of these must be enumerated the conviction, which its very earliest inquiries serve to convey, of the perfect harmony of the science with revelation, and the groundless nature of those fears which many well-meaning but mistaken persons so needlesssly entertain of the possibility of a collision between the two. This gratifying circumstance of the accordance of both will form the theme of too frequent and ample illustration, during the following pages, to require more than a casual mention here; and it may suffice to dispel the fears of those who may cherish such unnecessary appre-

hensions, if we state, that, in all essential points,—and we would particularly instance the date of the creation of man,—we find the records of Scripture fully and completely confirmed by the evidence of physical fact. Nay, we may go farther, and add that this admirable study, so far from lessening our belief in the Deity, or our perception of His attributes, cannot but tend materially to enhance and confirm our appreciation of both. A science, the professed object of which is to enlarge and increase our knowledge of creation, cannot but expand and exalt, in a commensurate degree, our admiration of the Creator. Those who would pursue the subject farther may be referred to the works of all modern geologists; the writings of a Lyell, a Buckland, a Delabeche, a Murchison; the orations of a Sedgwick, the lectures of a Mantell, and, in particular, those of Dr. Pye Smith, will furnish arguments so eloquent and convincing, as must suffice to remove the apprehensions of even the most sensitive and timid of inquirers.*

INSTRUCTIVE NATURE OF THE SCIENCE.—Geology has this, in common with all the studies of nature, that it teaches the unphilosophical character of our habitual ideas and impressions, and warns us to doubt even the evidence of our senses, until it is proved by scientific investigation to be true. Thus, while astronomy begins by convincing us, that the sun which we see to rise in the east, and to set in the west, performs, in fact, no revolution at all, but that the apparently unmoving earth it is, which really performs the daily round; so geology commences her instruc-

* See also an Essay on the Hebrew Language and Literature, by the Author. Sketches in Prose and Verse: Relfe and Co.

tions with truths not less, but even more repugnant to our pre-conceived sentiments and opinions. It unfolds the fact, that the present condition of our earth, far from being of primeval date and character, as is not unfrequently supposed, constitutes but one of the numerous vicissitudes through which it has passed in the course of its eventful history. The mountains which we deem of antiquity coeval with the earth itself; the hills which in our phraseology are "old," to a proverb; this science convinces us, are of very different dates, and have all, geologically speaking, been elevated at comparatively modern periods. Again, from the earliest times it has been the habit of man to associate the idea of stability with the land: and of fluctuation and change of level with the sea. Geology, however, demonstrates the very reverse of this to be the truth, and shows that while the land has undergone changes and disturbances the most violent and revolutionary, and has been the scene of elevation and depression, of intrusion and dislocation, on the most extensive scale; the sea, from its very nature, as a fluid, must have constantly maintained the same unaltered level. The stones and rocks, which we habitually regard as having ever been the hard, refractory, and unyielding objects which we behold them now; science, by the external characters which they bear, by the gentle impressions of organic structure which they present—by the tender foliage of the plant—the delicate markings of the shell—proves to have been thus imprinted when their substance was soft and soluble, and by this means convinces us that all stone, all rock, whatever now is hard, once was in the state of sand, of mud, or of fluid. These are but a few of the numerous instances which might be adduced, of the valuable and

instructive discipline of a science, which rids us of errors and prejudices derived from early habit and association, and implants in their stead more just and philosophical ideas of nature, and her Divine Author.

ANTIQUITY OF THE EARTH.—Thus while we are accustomed to regard our planet as coeval only with man, and as dating but from the five or six thousand years which science and revelation unite to prove as the era of his creation, geology demonstrates the far superior antiquity of the planet assigned for his abode. The mere investigation into the crust of the earth, that is, of the part accessible to human observation, will convince us that the substances of which it is composed, from their variety, extent, and order of succession, could only be the result of accumulation, continued through vast and incalculable cycles of time. We find that all the formations are aqueous and fossiliferous, with the exception of the granite, and gneiss, and mica-schist systems; though even these, according to the highly probable opinion of many geologists, were originally of like nature with the rest; the absence of stratification in the one instance, and of organic remains in both, having been occasioned by the intense heat which has reduced them to their present crystalline condition. The vast series of the remaining formations, and possibly even these, are therefore the mineralized beds of primeval oceans, with occasional but rare interpolations of fluviatile and lacustrine strata; the deposits of seas, or of rivers, and lakes, bearing in their stratified arrangement, and the fossil relics of the animal forms which once inhabited their waters, incontestible proof of their sedimentary nature and origin. They are, it is well known, of immense extent and area, the marine formations rivalling in space and grandeur

the vast Atlantic or Pacific; while the fresh-water floods appear to have vied with the enormous lakes and inland seas of the American continent at the present day. These aqueous accumulations, subsequently to their deposition, have repeatedly undergone the action of disturbing causes; the eruptive rocks have broken through the sedimentary deposits; and volcanic ejections, terrestrial and submarine, have exploded from below, have pierced and shattered the superincumbent beds; have forced and wedged their sheets of molten matter into the chasms of the strata they have divided; or bursting to the top, have poured their waves, and spread their terraces over the surface of the whole. Periods of intense volcanic activity have been followed by others of repose, which have again been succeeded by revivals of former energy; so that frequent alternations of this nature, of enormous extent and duration, have occurred, even in periods which are regarded as the most modern in the history of the earth.

In pursuing the natural and legitimate mode of interpreting the past by the present, and observing the effect of similar agencies in existing nature, we are forcibly impressed with the slowness of these operations at the present day. Lakes are ascertained to shoal up, or deposit sediment, in the proportion of only a foot in a century; and even oceanic deposits are known to be correspondingly tardy of accumulation. Hence we find that during the entire historic period, the physical geography of our globe, with the exception of local and minor modifications, has remained unaltered. The oceans, rivers, lakes and mountains recorded in Scripture, form the physical features of the same regions at the present day; and arriving at a more modern period, and at

localities less remote from ourselves, we find that the ocean which Cæsar crossed, still separates the Briton from the Gaul; that the same rivers water the capitals of the same countries of Europe; while the same Vesuvius which overwhelmed Herculaneum and Pompeii beneath its ejections, still threatens the surrounding districts; and the same sub-marine volcanic agency, which, as we have mentioned, alarmed the Roman people, still continues in activity, and produces similar phenomena, at the present day.

When, therefore, reverting from the present to the past, we contemplate those operations which have formed or modified the crust of our globe, and observe their extent and grandeur; when we find evidence, not of a single change, but of cycles of mutations; of seas on seas: with alternations of dry land in the existence of forests, rivers, and lakes; together with proofs of volcanic agency, with its long-continued intervals of action and repose; and when we reflect that nothing is made in vain, but that every created object has its sphere of usefulness, and therefore of duration; and when we look on the fair and harmonious world around us, and examine the diversified materials of which it is composed, and the wondrous agencies by which it has been elaborated into order, fertility, and beauty, we cannot avoid the conviction, so irresistibly forced upon the mind, that operations thus complicated and extensive, and results thus admirable and perfect, must have required an adequate period for their development; and that time, to an extent inappreciable, perhaps, by human powers of calculation, must have formed an essential element in the vast work of Creation.

ANTIQUITY OF THE UNIVERSE PROVED BY ASTRONOMY.

—It is the profound remark of Lord Bacon, that we must seek the explanation of a phenomenon not merely in the investigation of that object alone, but by comparing it with others of like nature with its own; and thus the antiquity of our earth, far from being inconsistent with the general plan of creation, is only in accordance with the most extensive and enlightened views which have been formed of the whole universe itself. The magnitude and grandeur of the phenomena which characterise the entire system, as far exceed those observable in our earth itself, as the whole must be conceived to transcend the part; and it may be stated, that if geology appear incredible, astronomy must seem impossible; yet, owing to the exact nature of the latter science, its truth and accuracy are of course susceptible of mathematical demonstration. The astronomer reveals facts so far surpassing our usual calculations and impressions, that the mind, unaccustomed to scientific investigation, might be warranted in rejecting them as fables, were it not that he, at the same time, foretels an eclipse to the fraction of a minute, and thus proves his system to be true. For instance, there are stars so incalculably remote from our planet, such as can only be reached by the telescope of a Herschel, that their light would require vast cycles of ages to arrive at our earth: and as these luminaries occasionally become extinguished or invisible, it results that we may actually be gazing on the light of a star, which has been lost to our sphere long before the creation of our race. Sir William Herschel, in a paper in the Philosophical Transactions for 1800,* *On the power of telescopes to penetrate into space*, a property distinct from the magnifying power,

* Dr. Pye Smith, on Geology, p. 368.

informs us of the existence of bodies which only his telescope can reach, which are situated nearly twelve millions of millions of millions of miles from our earth: whence it follows, that the light by which those objects have become visible to us, must have been nearly two millions of years in its progress. And since Scripture and science combine to assure us, that the whole of the material universe was created at the same period, this fact alone is sufficient to invest our globe with an antiquity of two millions of years, since the light of so distant a star could not have reached us in a less space of time. And when we reflect that we can by no means assume these points, however remote, to be the limit of creation, and that if we were removed to those distant orbs, we should as it were behold, not the end of the universe, but only its beginning, and should observe fresh spheres of existence, of harmony, and of beauty, extending throughout illimitable space, we must yield up our doubts, acknowledge the insufficiency of the finite to comprehend the Infinite, and cease from cavilling, to wonder and adore!

MODERN DATE OF MAN.—The comparatively modern period of the creation of man, and the inferior age of our race to that of the globe which we inhabit, is a fact revealed by Scripture and confirmed by science. The same internal evidence which convinces us of the extreme antiquity of our planet, affords the like satisfactory proof of the comparatively modern period of the origin of our species. The whole vast series of aqueous deposits are of course crowded with organic remains, with fragments of the weeds, plants, corals, shells, crustacea, fish, reptiles, birds and mammalia, relics of the vegetable and animal existence of the ancient earth;

but no fossil remains of the human form have yet been discovered in the solid rocks themselves; or in any, save those accumulations of silt, or mud, which date from the most modern era—the yesterday, as it were, in the infinite history of the past. It is only in these accumulations of the historic period, that we discover the remains of even the most ancient families of mankind: that in this country we meet with the implements or utensils of our British ancestors, or the coins and weapons of their Roman invaders; that in Italy we find the Cyclopean structures and works of art of the Etruscans, a nation who appear to have preceded the Romans in the occupation of Italy, and to have excelled them in civilization and the arts of life; while vestiges of the Pelasgi are alike discoverable in similar deposits in Greece; and in the new world, traces exist of the Tulteques, a people who seem to have been the predecessors of the Mexicans, and their superiors in knowledge and improvement. In the solid rocks, we repeat, no traces of man are discernible. Yet had the human race been really the aborigines of the physical history of our planet; had they actually existed in its primeval times, their remains would, unquestionably, have been found scattered throughout its varied deposits from the oldest to the most recent in the series. No impediment exists to their conservation; our bones, composed of the same elements as those of the animal races, are equally capable of being kept from destruction; the same battle-field has preserved the bones of the horse and his rider; the same cavern which, in earlier eras, gave shelter during life to the hyena, and the bear, and retained their skeletons after death, has alike preserved the remains of those human occupants, who, at a later

period, found, in the same retreat, a refuge and a tomb. But a still stronger proof of the modern date of our species exists in the obvious fact, that if man had really been an inhabitant of the earth during its early history, his skeleton, or the mere fragments of his osseous structure, would have constituted the least of those relics which he would have bequeathed to the soil, of which he was an inhabitant. We should have discovered his mighty and majestic works, which so far transcend in duration his own ephemeral existence. We should have found his cities and his structures overwhelmed in the waters of ancient seas, or buried beneath the ejections of primeval volcanoes; his majestic pyramids sunk in the bed of early rivers; his mountain-temples, hewn on the surface of the deepest and the oldest rocks; we should have encountered his bridges of granite and of iron; his palaces of limestone and of marble; the tombs which he reared over the objects of his affection; the shrines which he erected in honour of his God! But in the absence of these, or any other trace of man, in any, save the most superficial of deposits, we are compelled to acknowledge the chronology of Holy Writ; to recognise the complete and satisfactory accordance of science with revelation; and to admit that the existence of man has not extended beyond those five or six thousand years upon the earth, which the Scriptures assign as the period of his creation. It will be self-evident that this fact, like many others in natural science, far from lowering our ideas of the Divine perfections, serves only to strengthen and exalt them. It is, in fact, impossible to form a more magnificent conception of Infinite bounty and wisdom than that which reason and revelation here combine to offer: representing the Supreme Being as

first elaborating and perfecting our earth into one vast sphere of blessings; erecting, on a foundation of granite, a vast superstructure of sandstones, limestones, clays, shales, salts, coal, and the varied substances known as rocks: injecting their fissures and crevices with minerals and metallic ores; then, by the intrusion of volcanic agency, bringing these varied deposits near the surface, and so diversifying the soil as to present every variety of condition best adapted for its mineral, agricultural, and economical cultivation; tempering, as well, the climate to the degree best adapted for human health and enjoyment; peopling it with animals adapted for the use of man, for supplying him with food, and assisting him in his labours; and, finally, calling man himself into existence, to take possession of a world, which Infinite wisdom and benevolence had thus prepared and perfected for his reception and enjoyment.

Origin of the Earth.—Though cosmogony forms no part of geology, which, we are expressly cautioned by one of the most eminent authorities on the science (Dr. Hutton), has nothing to do with the origin of things; yet we may fairly indulge in an enlightened curiosity as to the original formation of our planet, and seek the most probable explanation of the mystery of its creation. Our guide in this inquiry must be astronomy; we must look from the earth itself to the kindred spheres which surround it, and from that world which it presents to our apprehension, to that far more extensive universe, of which the entire solar system constitutes a merely minute portion. The hypothesis which is conceived to offer the most philosophic and probable explanation of the origin of our earth, is termed the nebular theory; it first originated in the researches and

discoveries of the late Sir William Herschel and his distinguished son, and has been confirmed by the similar investigations of continental astronomers, as the celebrated Laplace, Gauss, &c. &c. The subject has been farther illustrated by the eloquent writings of Professor Nichol, and has been generally adopted as the most rational theory yet suggested of the formation of our planet.* As a brief summary of the hypothesis it may be stated, that Sir William and his son, in common with the foreign observers above named, were, for a lengthened period, in the habit of remarking appearances in the heavens, which appeared to them sufficient to account for the origin of new worlds. They observed that every portion of universal space abounds in large expansions of attenuated matter, reflective of light, which they termed *nebulæ;* these appeared of various figures, and in different states of condensation, from that of an extensive luminous cloud, a mere shapeless film, to masses of more defined outline and denser structure; thence to others which assumed a globular or spheroidal figure; thus graduating, through every variety of form and aspect, up to orbs of light, and suns, and systems like our own. It is scarcely necessary to add, that the conclusions of these distinguished observers were not founded on the changes perceptible in any individual nebula, since the duration of our whole solar system, it is conceived, would be inadequate to elicit any change in the condition of any single one of these; but were drawn from the contrast afforded by the numerous bodies of this kind diffused throughout space, which exhibit every stage of change and progression. Our solar system is conceived to have been created by this agency. The

* See Dr. Mantell's Wonders of Geology, vol. i. p. 22.

sun is inferred to have been alike the centre and parent of the system; for, existing primarily in the shape of a diffused nebula, it is supposed in the progress of rotation and condensation to have thrown off the planets of our sphere, as Herschel, Saturn, Jupiter, the Asteroids, Mars, the Earth, Venus, and Mercury, while the satellites are presumed to have been cast forth the last of the whole.

It will readily be perceived that this supposed gaseous origin of our planet contains, within itself, all the conditions requisite for its succeeding changes, and its present state; it being considered that the earth has passed from a gaseous to a fluid, and thence to a solid condition, as the varied processes of rotation, refrigeration, and condensation, have simultaneously proceeded; the spheroidal form which it now presents, enlarged at the equator and flattened at the poles, being precisely that which would be assumed by a fluid body rotating on its axis. When the first thin pellicle cooled, and hardened on its surface, the general physical divisions of the globe are conceived to have taken place, and the varied phenomena of animal and vegetable existence to have commenced. As soon as this outer film became sufficiently firm to receive and to retain the contents of the surrounding atmosphere, the earth assumed the distinctions of land and water, affording a sphere for the development of those germs of animal and vegetable life which exist in each, and giving rise to those physical and vital phenomena which, under diversified conditions, now prevail in existing nature; and the investigation into the past history of which constitutes the object of geological investigation at the present day.

To the mind unaccustomed to scientific inquiry, the

proposition that our globe itself, with all that it inherits, owes its origin to a mere cloud of vapour, may appear as strange and startling as many other of those phenomena which it is the purpose of natural science to demonstrate and to explain. We have only to advert to so familiar an object as water, to show that this fluid may be reduced to the most varied and dissimilar conditions by the mere influence of heat, or by chemical decomposition. By lowering the temperature we freeze water into ice; by raising it, we thaw ice again to water; by an increase of heat we convert it to vapour; while we can condense this vapour into water again, once more to freeze it into ice, or sublime it to vapour as we please. By chemical decomposition, we reduce it to its elements, the oxygen and hydrogen gases of which it is composed; and by applying fire to these we produce explosion, and evolve the phenomena of light and heat from objects, which, when in combination, constitute a fluid. Metallic substances are capable of like transmutations from the most solid form to that of mere vapour; and these facts, combined with others, as the internal heat of our globe, its volcanic eruptions, its vaporous exhalations and thermal springs, which latter have their rise, in some instances, from below the granite, serve to demonstrate the extreme probability of our planet having condensed to its present solidity, from the fluid or gaseous state: which this hypothesis assumes as its original condition.

Internal Heat of our Globe.—That our planet possesses a source of subterranean heat, is a fact which is demonstrated by the phenomena already mentioned. The increased temperature of wells and mines, the warmth of which augments in a very rapid ratio as we

descend; the vaporous exhalations of the earth, its streams of heated water, and in particular its volcanic eruptions, all prove the existence of such a cause. It is sometimes termed the central heat; but an objection has been urged against this term, and the epithets subterranean and internal proposed, on the ground that the heat, though of necessity subterranean and internal, is not of necessity central. To an agent thus powerful and universal many of the modifications of the earth's surface are evidently attributable, as the fusing the melted rocks, and the altering those which are termed metamorphic, while its operation in existing volcanoes is alike evident. The only doubt of importance remaining is as to the nature of these subterranean fires, a point respecting which the scientific world are divided, one section, among whom are Humboldt, Fourier, Cordier, and Arago, maintaining the views of Leibnitz, as to their resulting from the original incandescence of our planet; the other, attributing them to chemical agencies operating within the depths of the earth. Meantime there are various facts, such as the mean density of our earth, which is too small to allow of its being wholly a solid mass; together with the undulatory motion observed in earthquakes, with other phenomena of similar nature, which lead to the conclusion, that a large part of the interior matter of our planet, and that part immediately in contact with the crust on which we dwell, is in a state of fusion by heat, and that we are existing on the mere external covering of a mass of molten fluid. The oscillations of such a fluid tending towards different directions, will sufficiently account for physical phenomena of the highest relative interest and importance, such as the changes exemplified in the

external aspect of the earth by the elevation of continents from the bed of the ocean, the upheaval of some portions of the surface, the submergence of others, and the general variety observable in the configuration of our globe. These are questions which it is the peculiar province of geology to investigate, and which, though of immense extent and interest as regards the inhabitants of our planet, are of merely unimportant value when contrasted with the dimensions of the globe itself, and are susceptible of the clearest explanation, by a reference to those laws of nature, the power and prevalence of which are of self-evident reality and truth.

Crust of the Earth.—We are naturally directed to this covering, crust, coating, or rind, *Erdrinde*, (as the Germans in their significant language appropriately term it,) of the earth, as the legitimate sphere of geological investigation. These terms are used in a general sense, and without reference to any theory as to its internal structure or contents. It will be best understood if we describe it as that portion of our planet which is accessible to human observation. It is composed of a vast amount of substances more fully to be described hereafter, which, under the vague but convenient term of rocks, comprise every variety of element and combination, from loosely coherent beds of sand and gravel, down to crystalline rocks and masses of granite; and from the ashes and scoriæ of volcanic ejections, to the hardest and most compact kinds of trap and basalt.

It has already been observed that the crust of the earth, though of merely microscopic value as regards the dimensions of the globe itself, is of immense extent and importance with reference to mankind and the

organic beings which exist on its surface. As regards its extent, which is estimated at about ten miles, it bears, in a physical point of view, no greater relation to the mass of the globe itself than that which would be offered by a film of gold leaf coating the rind of an orange; but regarded under another aspect, it is the theatre of land and water, of mountain and valley, of ocean, river, and lake, and affords a sphere for the existence of mankind, as well as of the animal, vegetable, and mineral kingdoms.

ORDER AND SUCCESSION OF THE ROCKS.—The constant and unvaried sequence of the several geological formations constitutes one of the most important and useful lessons which this instructive science is calculated to convey, since on this fact, which may, at first sight, appear trivial or unimportant, depend some of the leading principles of geology, and their most valuable and practical application. It is well known that at a period comparatively recent, before the researches of science had been so extensively and systematically pursued as is the case at present, the utmost ignorance prevailed as to the structure of the earth which we inhabit. It was looked upon as a mere mass of confusion, the very chaos of classic antiquity, where all incongruous and heterogeneous substances mingled, all antagonist forces strove confusedly together. It was known that at some places there were solid rocks at the surface, and at others there were not; but this was regarded as a mere matter of chance: their order, succession, and continuity were unsuspected; for the laws which determine these results were undiscovered and unknown. It was reserved for geology to deduce harmony and regularity from the previous confusion,—to extend to an immea-

surable degree the domain of philosophy, and to enhance our appreciation of the Supreme Being by revealing fresh spheres of his creative wisdom and power. The arrangement of the various formations may be represented by an alphabetical series from *a* to *z*; and this order, though it is frequently imperfect, is never inverted. We often miss one or more terms in the series, and lose, say the *b*, or *h*, or *m*, or even several letters in succession; but we never find the *b* taking place of the *a*, or the *d* preceding the *c*, or any member of the series usurping the position of another which ought to go before it: in other terms, we never meet with the entire series of deposits, but those which do occur invariably follow a regular order of sequence. On a fact thus simple and obvious depend not only many of the most essential principles of the science in theory, but several of its most important uses in practice; for example, the search for coal. This substance, as will shortly be shown, is deposited among the lower secondary rocks, in other terms, very deep in the series, about the position, suppose, of our presumed letter *s*. Now, as we have every variety of rock occasionally presenting itself at the surface, from the sand and gravel of the metropolis to the granite of Cornwall, every letter, in short, from *a* to *z*, it follows as a matter of course that coal can only be obtained in localities where the surface-deposit appertains to a formation immediately overlying the coal, (usually the new red sandstone,) the letter *r*, it may be said, of our imagined alphabetical series. If, therefore, on the one hand, the search for coal is undertaken, as at Northampton,* in localities

* See page 14.

where the surface-rock lies considerably above the carboniferous deposits, the thickness of the intervening beds presents mechanical obstacles of insurmountable difficulty, and the works are liable to be stopped by the impenetrable mass of the strata, or overwhelmed by their springs or floods, long ere the sought-for treasure can be obtained. Or if, on the other hand, the surface-deposit lies actually beneath the carboniferous strata, constituting the *t* or *v*, or any succeeding letter of our symbolical alphabet, (as Mr. Murchison mentions to be frequently the case in the Silurian region,) the search is equally hopeless, and the object is sought where it never has existed. Principles which are thus plain and simple, and the inferences from which are so natural and so self-evident, would seem too obvious to require even mention, were it not that enterprises altogether hopeless are constantly undertaken, and fortunes squandered away, for want of a right understanding of propositions thus susceptible of the most easy and natural explanation.

TROPICAL CLIMATE OF THE ANCIENT EARTH.—Among the varied and striking contrasts afforded by the past and present condition of our globe, must be enumerated the fact which is so clearly demonstrated by the character of the several formations, and of the organic remains which they entomb, that the tropical climate and character of production now limited to the immediate vicinity of the equator, once extended over the whole earth, the refrigeration and change to a lower temperature having been relatively sudden and of recent date. It is only, says M. Deshayes, in the second era of the tertiary period,* the miocene of Mr. Lyell, that

* Coquilles Fossiles des Environs de Paris, p. 779.

the climate of the earth has cooled, from a degree of heat exceeding that of the equator at this moment, to a temperature equivalent to that of Gambia and Senegal, while it is only at a third and more recent epoch that it has assumed an European character. These results are deduced from the comparison of a suite of fossil shells with a series of recent species, from the localities above-mentioned. The observations of Count Sternberg, on the flora of the ancient periods, indicate analogous changes in the vegetation of these eras; while the discoveries of a Cuvier, an Owen, and a Mantell afford similar testimony as to the fauna of the primeval earth, and prove the extinction and substitution of successive races of animals. If we examine the whole of the fossiliferous beds with this view, commencing with the most ancient, we shall find that the organic remains which they contain, consist of polyparia and corals, such as are known to exist only at a short distance from the equator; of shells, chiefly referable to those of the torrid zone, while the crustacea are analogous to those of the Indian seas, and the fish bespeak a like tropical origin. Proceeding upwards to the coal, the earliest, and, with the exception of the wealden strata, the only evidence of the ancient earth afforded by the secondary formations, we find the testimony derived from the land confirming that deduced from the sea. We perceive the flora of that singular and instructive epoch to agree in its tropical character with the fauna of the oceans which preceded. The vast and overwhelming proportion of monocotyledonous over the dicotyledonous forms of plants, of trees allied to the fern, the palm, the cane and the bamboo; the rank and luxuriant nature of vegetable growth and developement, giving to mere mosses and ferns the elevation

and magnitude of the loftiest forest trees; the enormous extent of this vegetation, reaching, as it does, from Europe to Australia, and from this country to its antipodes; these, with other characters, derived principally from the comparison with allied genera of existing tropical plants, amply prove the earth, during this period of its history, to have possessed a universal climate, the heat of which was not merely as elevated as that of the tropical regions at this moment, but which, we are assured by M. Adolphe Brogniart, as far surpassed the tropics as they exceed the temperate zone at the present day. As we advance upward in the scale of formations, the proofs of the same fact become more obvious and conclusive; since, on arriving at the new red sandstone, we reach that age of reptiles which the discoveries of a Mantell and the labours of an Owen have so firmly established and so widely extended; and finding reptiles of crocodile, lizard, or fish-like types, as far exceeding in size and proportions the lizards and crocodiles of the tropics as these surpass the diminutive reptiles of our colder regions, we perceive that a climate of ultra-tropical intensity must have alike been requisite for the developement of forms of life, such as could not have existed in a less elevated temperature. And, when proceeding onwards, we find no evidence of refrigeration, until we reach the very modern period to which we have alluded, the concluding term of the tertiary series, we cannot resist the conviction that the ancient earth, during almost its entire history, enjoyed a universal climate, the heat of which was not merely equal, but superior to that of the torrid zone.

Various hypotheses have been proposed to account for so important a difference. Mr. Lyell has suggested that a reversal of the present distribution of the land

and sea would afford a sufficient cause, and has imagined that if a greater developement of land now prevailed in the southern hemisphere, and of the waters in the northern, as is presumed to have been the case in the early conditions of our globe, its ancient climate would be restored. Mr. Babbage, with considerable appearance of probability and truth, has sought the cause in the radiation of internal heat, suggesting that the accumulation of fresh deposits, and the substitution of sedimentary substances, which are a bad, for water, which is a good conductor of heat, may have been adequate to the result. Other inquirers, again, have referred the change to astronomical causes, and Sir John Herschel has recently suggested a theory, which has every appearance of probability, and which is in substance as follows:—He first states that the amount of heat derived by the earth from the sun increases or diminishes with the eccentricity of the earth's orbit; and that this eccentricity is known to be slowly decreasing. He next shows that the actual eccentricity of many of the planets is known to be very considerable indeed; and he concludes that we have only to form the very natural conception, that this eccentricity of the earth's orbit has formerly been greater than it now is—equal, in short, to that of several of the planets at this moment, when we shall at once perceive, that the slow diminution of such eccentricity may have produced a refrigeration of climate, equal to that indicated by the geological phenomena under our review.

Whatever be the cause, however, the fact is indisputable; the tropical climate of the primeval earth is demonstrated by the universal character of its productions; and we are compelled to admit that a cause then prevailed, or, possibly, a combination of the causes

above enumerated, which was sufficient to overcome the effect of the diurnal and annual motion of the globe; in other terms, of the change of seasons, and to render its surface one vast hot-house, as it were, calculated for the growth of ultra-tropic forms, both of animal and vegetable existence; while the circumstance is one which the student must regard not merely as an abstract truth, but as a principle fraught with the most useful and instructive application. No lesson in science is more difficult than that which teaches us to dismiss those impressions which early habit and association have rendered familiar, and to substitute for them opinions which, though more philosophical and correct, are strange and new. In investigating the ancient history of the earth, we must entirely dismiss all idea of its character as it exists at present; we must change land to sea, and sea to land; we must transfer ourselves to distant regions, and to torrid climes; we must regard its oceans as vying in extent and grandeur with the Atlantic or Pacific, abounding in corals, reefs, and islands, and with tropic forms of marine existence; its lakes must be inland seas; its rivers such as rival the Amazon or Mississippi; its forests groves of ferns, canes, palms, bananas, and bamboos; its plains luxuriant savannahs, overgrown with rank grasses and gigantic reeds, giving shelter and subsistence to dragon-like types of life; the whole scene must present the panorama of a torrid clime, with its colossal forms of animal and vegetable existence; and we must reverse the condition of all around us, till

> "Nothing is,
> But what is not!"

Arctic Climate.—From various phenomena which have already been mentioned, in particular the occurrence of erratic blocks, the presumed existence of ice-

bergs, glaciers, and fields of ice, as well as from the arctic character of many fossil shells, it is conceived that at a comparatively recent period, probably towards the close of the tertiary epoch, the tropical temperature of the ancient earth was succeeded by a climate of greater cold than now prevails in the same regions at the present day.

EXTINCTION OF VARIOUS RACES OF ANIMALS.—This is a circumstance of so obvious a nature, that a mere notice of the fact wiil be sufficient for our present purpose. It may in brief be stâted, that when the conditions of nature, particularly with reference to climate, were favourable to the existence of certain forms of animal life, such creatures were called into life; and when nature became unfavourable to their well-being, they were recalled from existence, and their places supplied by other races better suited to the altered condition of the earth: the change, as Mr. Lyell observes, not being sudden or violent, but gradual and gentle—one species or genus becoming extinct after another, and their place being occupied by fresh forms, so that no void was left in nature, until, after a certain epoch, the fauna of a country was gradually but completely changed.

The student may remember with advantage, that in proportion as we recede from the present era, in that proportion the animal types become wild and strange, and dissimilar to those now in existence; while the converse of the proposition of course holds good, and in proportion as we approximate towards the existing period, in that proportion the animal forms soften down, as it were, and approach more nearly to those by which we are surrounded at the present day.

OPERATION OF MODERN CAUSES.—Lessons of this

nature might be extended to an entire volume, but we will conclude the present series with the repetition of one which forms the chief design of the excellent work of Mr. Lyell, and which, though conceived by preceding philosophers, he has the honour of having first fully illustrated and explained. It is, in substance, that while nothing in nature is either permanent or primary, and while the great metempsychosis of matter is continually going on, the laws which regulate its changes are immutable, imperishable, and immortal. The mutations which have occurred on the face of the earth are essentially the same with those in action now; and where existing causes might seem inadequate to produce these results, they are conceived to have been effected by the operation of such causes having been continued during vast cycles of time. The history of primeval nature, in short, is believed to have been similar to that of nature as she exists at present. Her usual course has been one of tranquillity and repose, but she has also experienced paroxysm and convulsion, the volcano and the deluge, the fire and the flood; yet even these have been controlled and harmonized to order and beauty, by the overruling Providence which first created this wondrous universe, and ever will watch over it till the last moment that its existence shall be permitted.

EXERCISES.

The statements of the foregoing chapter in themselves constitute so many exercises. The following examples may be added for further illustration.

1. The first lesson in the chapter, that of the innocency of such studies, and of the aid which they afford in enabling us to appreciate the attributes and perfections of the Deity, is enforced by every inquiry into his works, in which it is possible for the mind to engage. The mineral, vegetable, and animal kingdoms vie with each other in displaying the perfections of their Author; and since geology is only another name for the combination of all the studies of nature, it is evident that no other pursuit of a similar kind can afford proofs so numerous and instructive of the benevolence and wisdom of the Creator as are presented by this all-embracing science.

2. In illustrating the antiquity of the earth from the foregoing chapter, the object will be facilitated by the student converting its statements into questions, and rendering the answers which are calculated to explain them. He will further find it expedient to insert these and other points in his note-book, and to enter under each respective head the information which bears upon the particular fact.

3. The modern date of man, as contrasted with that of the earth of which he is an inhabitant, is a truth of so self-evident a character as to require no effort or anxiety for its demonstration, since on this and other statements of the present chapter the difficulty would be not to establish the fact, but to discover a single argument which would be found to militate against it.

4. In theorizing as to the nature of the internal heat of our planet, the student will find ample information on the various hypotheses in the works of those authors by whom they have been suggested. It is obvious, however, that questions of so abstruse a nature are rather

fitter for the proficient than the tyro; and the beginner may rest satisfied at the outset with the unquestionable fact of the internal heat of the earth, without indulging in those speculations as to the origin, which the progress of philosophy up to the present moment has not fully enabled us to determine.

5. The nature of the crust of the earth, and the texture, order, and succession of those substances of which it is composed, are themes respecting which it is scarcely possible to suggest any definite exercises, further than the mode already suggested, of self-examination by converting the statements of the previous chapter into questions, and returning the appropriate answers.

6. The tropical climate of the ancient earth, the changes in the types of animal and vegetable existence consequent on its refrigeration, and the nature and effects of modern causes, are in like manner facts, respecting which no exact tasks can be assigned, and the student will find the most instructive mode of studying these, and similar principles, to consist in transferring the heads of them to his note-book, and making them the subject of those remarks and illustrations which will not fail to suggest themselves in the course of his geological studies.

CHAPTER IV.

QUALIFICATIONS OF A GEOLOGIST—INSTRUCTIONS FOR THE BEGINNER—PRACTICAL HINTS FOR COMMENCING THE STUDY OF THE SCIENCE—SCIENTIFIC INSTITUTIONS—WORKS ON THE SCIENCE—COLLECTING, ARRANGING, AND DESCRIBING FOSSILS—THE MICROSCOPE—LECTURES IN GENERAL—LECTURES AT THE BRITISH MUSEUM.

Qualifications of a Geologist.—It will be perceived from the foregoing remarks, that geology is a science far too extensive and universal to be completely and successfully studied, in all its details, by any single mind. In fact, the perfect geologist, like the perfect orator of the Roman writer, is to be regarded rather as a creature of the imagination, than a being of real life and actual occurrence. Such a person ought to be versed in the complete circle of science, philosophy, and letters, and to possess attainments which a whole life is scarcely sufficient to acquire. He should be acquainted with the mathematics and general physics, that he may be enabled to judge of the nature and importance of the facts submitted to his investigation, and of the inferences which may be deducible from them. He should base his researches in geology on a sound study of mineralogy, that he may be enabled to judge of the internal structure and external characters of minerals and their combination in rocks. Chemistry should claim his attention; he should possess some familiarity with its laws, and some practical proficiency in analysis,

experiment, and general manipulation. He should acquire an extensive and well-founded acquaintance with conchology, so as to attain the power of detecting the minute but characteristic distinctions of species, and even varieties, both of recent and fossil shells. His skill as a botanist should be accurate and profound, so as not only to enable him to describe a recent plant, or trace a flower, but to determine from the fragmentary mineral relics of vegetation submitted to his inspection, from the veins of a leaf, the markings of a stem, or the character of a seed-vessel, imperfectly as these objects are presented to his view, the tribe or family to which the plant belongs, and to connect its occurrence with the general nature of the stratum in which it is discovered. He should not only be so far acquainted with comparative anatomy as to be able to identify the character of a single tooth or bone; but he should possess somewhat of that more profound and more accurate acquaintance with the laws of structure, which has enabled a Cuvier, a Mantell, an Owen, and a Grant, to restore the entire creature, and bring the extinct forms of by-gone eras again to life. He should possess the accomplishments of a draughtsman, and, to some extent, the skill of a surveyor. He should be a classical scholar—should possess a sound proficiency in the learned languages, to enable him, in particular, to deal with the delicate question of nomenclature; and should, in like manner, be versed in modern tongues, for the purpose of corresponding and conversing with foreign philosophers, of reading their productions, and keeping pace with their researches and discoveries. He should possess the accomplishments of literature, and the attractions of an animated and pleasing style. It were

desirable that he united with these the abilities of an orator; that he were capable of conveying to his hearers the knowledge which he has acquired himself; and of transferring to the minds of others that admiration of nature and her perfections, which should form the paramount feeling of his own. It is obvious, that pursuits thus varied and extensive can scarcely be combined in any one individual:

> "Natura certè
> Multa tegit sacra involucra, nec ullis
> Fas est scire, quidem, mortalibus omnia!"

Since, therefore, none of our living geologists can boast the whole of these attainments, though many possess a considerable part; and since the mastery over subjects so profound and extensive is, obviously, not to be acquired by a single student, geology, becomes, in an eminent degree, a co-operative pursuit, a study which no unassisted individual can grasp, but which all may assist to promote. Accordingly, our best and most eminent geologists, while they devote a due attention to the general objects of the science, confine their peculiar energies to some single department, bring to the general stock the information they individually acquire, and store in the common depository the produce they collect in many a separate field. In a science thus dependent on the labours of many, the efforts of all are useful; and while no labourer can call the territory his own, the tyro and the pupil may contribute to its cultivation. A very moderate acquaintance with its leading principles and auxiliary studies will authorize us to commence our career; a like moderate share of application will enable us to pursue it with satisfaction. When we have acquired the first lessons and general

outlines of the science; when we are acquainted with the nature and classification of the various formations; when we can distinguish aqueous deposits from igneous, and stratified from unstratified rocks; when we can specify the sedimentary deposits by their due appellations, and further recognise them by the distinguishing features of mineral character, order of superposition, and characteristic fossils; when we also know some ten or dozen of the simple minerals, and can detect their combination in rocks; when we are acquainted with the like number of the genera of shells, appertaining to each formation, and a similar amount of plants: in other words, when we have learned a few lessons, and filled a few drawers with a few fossils, and can bestow on each its local habitation and its name, we may fairly commence a career, the further prosecution and ultimate success of which will depend solely on our own energy and determination.

The first difficulties, however, are ever the most arduous, and with the view of assisting the tyro to surmount them, we shall now proceed to furnish a few practical hints, which may tend to facilitate his progress, and render his task comparatively easy and delightful.

The Scientific Societies and other Advantages afforded by the Metropolis.—The student, if a resident in the capital, should, in the first place, procure a ticket of admission to the library of the British Museum, by which means he will obtain access to works too voluminous and expensive for a private collection. Such a ticket is to be procured by applying to the principal librarian, and producing a recommendation satisfactory to a trustee or an officer of the house.

He will also find it expedient to avail himself of the advantages afforded by the scientific collections of the Museum; and the departments of Zoology, Botany, Mineralogy, and Fossil Organic Remains, may be advantageously studied by the aid of the Synopsis.

The Geological Society will conduce, in an important degree, to his information; he should inspect its collections, consult its transactions and proceedings, and, above all, attend its meetings, and witness its discussions, with the view of deriving that instruction which so distinguished a body is eminently calculated to convey. That mind must indeed be obtuse, those feelings must indeed be dull, which can derive neither instruction nor animation from the splendid gladiatorship of science, displayed by such combatants as a Sedgwick, a Buckland, a Lyell, a Murchison, a Fitton, a Delabeche, an Owen, a Mantell, and their fellow-*savans*.

The Museum of Economic Geology, at No. 5, Craig's-court, Charing-cross, is an establishment, the importance of which is only beginning to be appreciated by the public. It has long been matter of regret, that we possess, in this country, no School of Mines analogous to those establishments on the Continent, where instruction in the elementary departments of mining, and its associate sciences, could be procured. A gentleman, deservedly celebrated for his writings and labours in the cause of geology, Sir H. T. Delabeche, has, however, prevailed on the Government to supply the deficiency, in some degree, by forming a museum for the collection of ores, minerals, building-stones, models of mines and works, together with an office for the records of mines, laboratories for experiments, &c., &c. The establishment is, as yet, but in its infancy, but its im-

portance and value are recognised wherever it is known; and it cannot fail to prove of national value and importance, and incalculably advantageous and beneficial to all parties connected with the mineral cultivation of the soil.

The Royal Institution will afford excellent opportunities for acquiring chemical and general scientific knowledge. The Linnæan, Zoological, Entomological, and Microscopic Societies, offer every facility for the prosecution of those studies which they are especially designed to promote. The means of obtaining scientific information have also been largely increased by the establishment of the two metropolitan universities. Lectures on the leading departments of science are delivered at King's College and the London University, and the higher classes, even of the junior school, are instructed in natural philosophy. In several private establishments, the same course of education is pursued, and the author is permitted to mention that of Messrs. Nesbit, of Kennington-lane, as an academy where the pupils receive tuition in chemistry, geology, and the principles of natural and physical science. Classes for the study of chemistry are also formed at the Polytechnic Institution. And should the number or expense of these establishments deter the student of limited means from having recourse to them, such a person will find a highly favourable opportunity for cultivating several of the most important branches of knowledge, at the Mechanics' Institution, Southampton-buildings, Chancery-lane. The library is extensive, and well selected; the collections, both of minerals and fossils, valuable and instructive; lectures are delivered twice a week, on subjects of scientific and literary in-

terest; classes are formed for the especial cultivation of natural history, botany, mineralogy, and chemistry; and as the students, in addition to the public discourses, possess the opportunity of delivering class-lectures, and performing experiments, the establishment will be found to combine the advantages of theory and practice, in an eminently useful manner, at a very moderate expense. Similar privileges are afforded by other literary and scientific institutions; and several valuable private collections are accessible to the student, among which are those of Mr. Bowerbank and Mr. Saull.

WORKS ON GEOLOGY.—The works best adapted for each particular department will be named under their respective heads. We shall now enumerate, in alphabetical order, those publications calculated for the general study of the science, with a slight reference to the peculiar and characteristic merits of each.

The Introduction to Geology, by Mr. Bakewell, is one of the most instructive and useful works published; especially as regards the mineralogical department of the subject.

The Bridgewater Treatise, by Dr. Buckland, contains a like able exposition of the chief phenomena of geology, and of the design of the Deity, as displayed in the creation. In pictorial beauty, accuracy, and taste, this work is, perhaps, unrivalled in scientific literature.

The various productions of Sir H. T. Delabeche are highly interesting and meritorious; and his excellent Manual, in particular, contains an instructive account of the various formations; while his other writings are eminently valuable for the information they

afford on what is termed physical geology; the deposition of sedimentary rocks, their disturbance by igneous agencies, the action of rivers, streams, currents, and all that is usually regarded as comprising the dynamics of the subject.

The writings of Mr. Lyell are, as is well known, of the very highest order of merit. His admirable Principles contain a most valuable collection of facts, with the most able and philosophical reasoning on these data; the work may be considered, in short, an encyclopædia of the science; while his Elements, though avowedly designed merely for the tyro, are replete with instruction for those who are proficients in the study.

The whole of the writings of Dr. Mantell are deservedly prized, both by the scientific and general public. The Fossils of Tilgate Forest, containing an account of his remarkable discoveries in that singular district, which he has rendered classic ground for the geologist,—his Fossils of the South Downs, and his Geology of the South-east of England, were all highly popular; when his Wonders of Geology surpassed in public favour all his previous writings, a greater number having, we believe, been sold within a given period than of any other work on the subject. This publication has, moreover, been translated into German, and republished in America.

The Silurian System of Mr. Murchison comprises not only a most accurate and laborious delineation of the peculiar district, so ably explored by this indefatigable observer, but an instructive review of the phenomena connected with the middle and lower formations. It is, in fact, the most splendid monograph, the most

admirable work on a single subject, which has yet appeared in the scientific literature of this or perhaps any other country.

The writings of Professor Phillips are in the highest degree attractive and meritorious. His treatises on geology, in the Encyclopædia Metropolitana and the Cabinet Cyclopædia, are, perhaps, the best and most instructive in the language; and his Guide, an unassuming volume, contains more information of value than many a more ostentatious work.

It is impossible to pass over in the list of writings on geology, a publication, the primary object of which was not to convey instruction on the science, but which contains a store of varied and valuable information: I allude to the able, and learned, and highly successful attempt of the Rev. Dr. Pye Smith to reconcile the discoveries of geology with the facts related in Scripture, and to demonstrate the perfect harmony of science with revelation.

The above are the most important and valuable publications known to the writer; and the student may safely commence his studies under the auspices of either of these highly able and instructive guides.

A Dictionary of Geological Terms will be found extremely useful; and that of Dr. Humble, or the smaller publication of Mr. Roberts, may be consulted with advantage.

The Geological Chart of Sir H. T. Delabeche will prove highly instructive; a good geological map will also be indispensable: that of Mr. Greenough, which is published under the sanction of the Geological Society, is the largest and most comprehensive. The writer has made use of that of Mr. Knipe, and found it extremely

accurate, particularly in certain complicated districts, among which the coal-field of Manchester may be especially noticed. Mr. Betts, of Compton-street, is on the eve of publishing a geological map which will possess the recommendation of being lower in price than any hitherto submitted to the public.

Mr. Bartlett has also recently published a valuable *Index Geologicus*, containing, on a single sheet, a geological, mineralogical, botanical, and zoological chart of the formations; presenting at one view a sketch of the whole succession of the deposits—their animal, vegetable, and mineral characteristics, together with an account of their agricultural soil and productions.

We cannot too strongly impress on the student the great advantage of a common-place book. He should, indeed, have one for each department of the science—general geology, the minerals, the shells, and the plants. It should possess an alphabetical index, and if he enter under its proper head the works of the various authors on these subjects, the fresh discoveries continually made, and, in short, all the information he can collect, he will very speedily find this to be the best and most instructive volume in his library.

It will be expedient to procure a collection of fossils and minerals, and these may be obtained of the following gentlemen: Mr. Heuland, (minerals only,) Red Lion-square; Mr. Sowerby, 50, Great Russell-street; Mr. Stutchbury, 47, Theobald's-road; and Mr. Tennant, 149, Strand. He will further require information, and these gentlemen are eminently calculated to afford it: they either give instruction, or are at all times accessible for the purpose of imparting intelligence.

There are numerous collectors and dealers in fossils in various parts of the country, in all the great fossiliferous districts, as the crag, the chalk, the oolite, lias, coal, silurian, and old red sandstone formations. Among others known to the writer, Mr. Taylor, of Blakeney, has obtained some admirable specimens from the crag; Mr. Deck, of Cambridge, has formed a general collection; Mr. Thatcher, of Brighton, procures specimens from the chalk; Mr. Rose, of Denton, near Grantham, has collected extensively from the oolite, and discovered two specimens of plesiosaurus from the lias, one of which is in the British Museum; Mr. Dudfield, of Tewksbury, has also discovered some valuable lias specimens, and has recently obtained a splendid specimen of ichthyosaurus; the Messrs. Ripley, of Whitby, have published an extensive list of fossils from the lower oolite and lias; Mr. Read has procured some admirable samples of coal-plants from Gristhorpe Bay and the vicinity of Scarborough; Mr. Gray, of Dudley, has collected largely from the Wenlock or Dudley limestone of that neighbourhood; Mr. Needham, of Castleton, has an assemblage of the minerals of the carboniferous limestone of the Peak; and Mr. Vallance, of Matlock, an extensive collection of similar objects.

Collecting Fossils.—If the collector reside in a district abounding in fossils, as, for example, the crag, chalk, oolite, lias, coal, or Silurian formations, or, still better, if in a spot near the junction of any two deposits, the task of forming a collection will be rendered comparatively easy, since his immediate neighbourhood will afford an abundant supply of objects of interest; and by exchanging the productions of his own locality for those of another, as, for instance, chalk fossils for

those of the coal, or oolite specimens for either, he will be able, with the aid of a few occasional purchases, to form an assemblage calculated not only to minister to his own improvement and satisfaction, but to contribute to the advancement and promotion of the science. The largest and most important collections have been accumulated not under circumstances favourable to the prosecution of such pursuits, but under difficulties and discouragements calculated to repress them. Amid other and more pressing occupations, as a solace in the evening from the occupations and fatigues of the day, have these treasures often been silently and gradually collected, until the cabinet of the amateur has grown into the public museum; and, as in the case of that of Dr. Mantell, has been deemed worthy of acquisition by a nation.

There are, perhaps, few, if any, general rules which can be suggested with advantage to the collector, further than to caution him against appearing too eager in his object, otherwise he will be likely to spoil the workmen, who are usually an ill-judging class of men, accustomed to form the most extravagant anticipations as to the worth of these objects, and feeling corresponding disappointment if their expectations are not complied with. The better course with such persons is, perhaps, to warn them at first against attaching too much importance to the value of fossils, and to accustom them to regard these objects not as a means of obtaining a livelihood, but merely as contributing an addition to their usual earnings.

Exchanging Fossils.—The procuring fossils by way of exchange is in many cases a very desirable, but in all a very delicate mode of proceeding, since there are

occasionally parties whom it is difficult to convince that they have received the full equivalent for what they have given. It will, therefore, be found most satisfactory to offer somewhat more than an equality, as 125 specimens for 100, or, in short, any proportion calculated to ensure the independence of feeling of the party suggesting the proposal.

Arrangement of a Cabinet.—The simplest mode of arranging a collection is, by placing the specimens in drawers sufficiently deep to receive them. If room suffice, the case should contain drawers on each side, with an arched glass frame at top for the display of those objects which are particularly calculated for exhibition; or the whole may be placed under glass, if there be sufficient space. The shells should be gummed on boards covered with paper, which may be obtained of Mr. M'Lellan, 107, Great Russell-street, Bloomsbury; Mr. Topping, 1, York-place, Pentonville, &c. Wherever it is possible, two specimens should be obtained of each shell, to display it both in back and front; and when the specimens are peculiarly interesting and instructive, the number may be increased.

The arrangement, of course, should be of a descending order, commencing with the formations of most recent, and proceeding downwards to those of most ancient date. It is much to be desired that a stratigraphical collection were formed at the British Museum: that of the Geological Society is, of course, restricted to its own members; but a cabinet of this nature at the national establishment, which should be accessible to every student, would materially conduce to the public utility and advantage.

The following gentlemen, among others, are well

known as draughtsmen and artists of distinguished talent in connexion with natural history:—M. Dinkel, M. Scharf, Mr. Sowerby, and Mr. Nibbs.

The reader is referred to the Appendix* for a copy of the Instructions for collecting Specimens of Geology, published by authority of the British Museum; which is from the pen of C. König, Esq., keeper of the minerals in the National Establishment.

THE MICROSCOPE.—Knowledge is ever progressive, and leads us gently and almost imperceptibly to results which are scarcely anticipated at the outset of our inquiries. Geologists, who some years ago commenced their observations with the eye, and were astonished at the spheres of life and being thus revealed, now extend their observations to an incalculable extent by the aid of the microscope, and obtain an insight into worlds unknown and unsuspected before. This simple instrument proves an auxiliary of the highest value and importance: applied, for example, to coal, which has been sliced and prepared for inspection, it not only decides a question which twenty years ago was one of the gravest uncertainty and doubt, whether coal is of vegetable origin, formed of the buried forests of the primeval earth, as the woody structure revealed by the microscope clearly proves, but it defines the very kind of plant to which the fossil belonged when it grew a forest tree of those regions in which it is now preserved in a mineral condition. Again, if applied to rocks of calcareous character, it alike displays their animal origin, and shows that the vast masses which make up the solid strata of the earth, are composed of the aggregated skeletons of minute creatures which once lived

* See Appendix A.

in its oceans, rivers, and lakes, and were entombed in the sediments deposited by those waters. While these are its effects as applied to solid rocks and substances apparently inorganic, its results when directed to the investigation of animal structure are still more wondrous. In the hands of an Owen and a Mantell it becomes an instrument of magic power, by means of which, from the inspection of a bone or a tooth, the colossal reptiles of the ancient earth are revived in all the reality of life and being, and the early formations of the earth peopled with their former inhabitants again.

While such are the objects at present achieved by the microscope, its future advantages in extending and advancing scientific discovery, it is scarcely possible to anticipate. Of such essential importance is it deemed in the cause of science, that a microscopic society has been formed, chiefly under the auspices of Mr. Bowerbank, for the prosecution of these inquiries, of which Professor Owen, and most of the leading naturalists, are members. A good microscope is, in fact, an indispensable requisite for the geological student, and will be found amply to repay the cost of its purchase. The best instruments are considered to be those made by Mr. Powell, 24, Clarendon-street, Clarendon-square; Mr. Ross, Featherstone-buildings, Holborn; Mr. Smith, Ironmonger-row, St. Luke's; and Mr. Palmer, 122, Newgate-street. Mr. F. J. Gould, 151, Strand, also manufactures both compound and oxy-hydrogen microscopes. Objects for microscopic investigation, both recent and fossil, are prepared by Mr. Topping, York-place, Pentonville, Islington; and by Mr. Darker, 9, Paradise-row, Lambeth.

Lectures. — These constitute a highly efficacious means of instruction, since they serve at once to excite and to gratify a taste for scientific pursuits. If the student himself aspire to lecture to a class, or an institution, such a task will prove extremely useful and instructive, since, in every department of knowledge, we find that the teaching others is the best method of perfecting ourselves. Opinions vary as to the mode in which a lecture should be prepared; and whether a written composition or an extemporaneous address is calculated to be more effective. A middle course is perhaps to be preferred, and it may be found most expedient, if the lecturer commit to writing the commencement and the close of his discourses, and leave the middle and illustrative portions to his own impromptu powers. Lectures, in fact, though they are to be regarded chiefly as incentives to study, and though they never can supply the place of personal application, yet, in conjunction with other means, are recognized as forming a highly valuable method of improvement; and those, for example, which were delivered by Dr. Mantell, at Brighton, may be cited not only as having proved in the highest degree interesting and instructive in their delivery, but when given to the world, through the medium of the press, as having formed a work which has scarcely its rival in popularity and success. A similar tribute is due to Professor Von Leonhard, whose admirable and highly popular treatise, cited page 77, was first delivered in the form of lectures at Heidelberg. Field lectures, (or what may fairly be termed *clinical* discourses, since they are delivered beside the *beds*,) such as are given by Professor Buckland, at Oxford, or

Professor Sedgwick, at Cambridge, are admirably calculated to convey information on the practical portions of the science; and the reader is referred to the Appendix* for the narrative of a most instructive and delightful discourse of this nature by Dr. Mantell, in the vicinity of Brighton.

PUBLIC LECTURES.—So eligible and so obvious, indeed, is this method of diffusing information, that all the scientific persons examined before the Committee of Enquiry of the House of Commons, in 1836, were unanimous in recommending that lectures, on subjects of scientific interest, should be delivered at the British Museum. No objection was stated at the time; it is true a doubt was expressed, that if the officers of the Museum were required to lecture, the collections would suffer in consequence; but a moment's reflection would show that no real grounds exist for such apprehension. In the first place, the collections are, in fact, only a means to an end; and are valuable to the general public, only in proportion as they are explained and understood, and rendered the medium of improvement and instruction; in the next, the task might easily be so apportioned, that each individual would not be required to lecture more frequently than once a fortnight, or possibly, once a month; and, lastly, so widely, and so permanently would an interest in these pursuits be diffused and established, that presents and offerings would flow in, from all quarters, and the collections, far from suffering, would be largely increased and enriched. The plan is perfectly facile and practicable. Fit up one of the apartments, or erect a new one in the quadrangle, as a theatre for lectures on public days; exact a small sum,

* See Appendix B.

a sixpence or a shilling, for admission, to preserve order and prevent intrusion; let the lectures be given by parties belonging to the Museum, or approved substitutes; let the first, and, in fact, all the discourses be plain and popular—the more so the better:—and the plan once commenced could not fail to prosper; while the establishment would be immeasurably enhanced in value and importance; since it is obvious that were all its treasures of science, letters, and the arts rendered conducive to popular instruction, it would become an engine of incalculable power and influence, in promoting the intellectual advancement and moral improvement of the people.

Objections to the Proposal of opening the Museum on Sundays.—Such a measure could not fail to prove far more useful and advantageous than the very questionable step recently proposed of opening the establishment on a Sunday; which, among other difficulties, presents this objection, that every infringement of the sabbath, far from benefiting the lower classes, for whose advantage it is ostensibly designed, is ever found to be ultimately detrimental to their welfare. Open public institutions on this day, and private establishments would speedily follow, till the working classes would be wholly deprived of that day which has been and ever should be consecrated as one of rest.

Public Lectures established by the French Government.—The question of lectures, at the Museum, may be regarded, in fact, merely as one of time. On the one hand, there exists so strong a desire for information on the part of the public, and on the other the trustees are so desirous to comply with this feeling, that it is quite impossible we can very long

remain in arrear of our Gallic neighbours in this particular, who have verified the adage, that "they manage these things better in France," and while we have been five years in complying with the recommendation of our men of science, have long since obeyed the suggestion of theirs, and have established lectures on the plan here recommended, at the *Jardin des Plantes* and elsewhere. These lectures being intentionally of a popular and elementary kind, and being seconded by introductory treatises of like nature, published by the lecturers and professors, have proved eminently instructive and beneficial.

CHAPTER V.

MINERALOGY.

OUTLINE OF THE HISTORY OF THE SCIENCE—CRYSTALLIZATION—CRYSTALLINE FORMS—SYSTEM OF MOHS—INSTRUCTIONS FOR FORMING A COLLECTION — INVESTIGATION OF THE EXTERNAL CHARACTERS OF MINERALS—USE OF THE BLOWPIPE—PRACTICAL EXERCISES, &c., &c.

AUTHORS:—PHILLIPS, BROOKE, GRIFFIN, THE ABBE HAUY, BEUDANT, WERNER, BERZELIUS, WEISS, MOHS, NEWMAN, &c., &c.

COLLECTIONS:—THE BRITISH MUSEUM, AND THE COLLECTIONS OF THE UNIVERSITIES AND PUBLIC INSTITUTIONS.

THE studies which are termed geology, consist essentially of mineralogy, physical geology, fossil conchology, fossil botany, and palæontology. As these pursuits are of the most extensive nature, as each would, in fact, demand the study of a life to acquire, while it would alike require an entire treatise to discuss it, we shall content ourselves with offering that elementary and practical information which will serve as an introduction to the larger works on each separate study, to which we again beg to refer the student for more ample particulars.

We have already remarked that a proper acquaintance with mineralogy must form the basis of all sound knowledge of geology. There are substances of common geological occurrence, which are so similar to each other, that they can only be discriminated by an acquaintance

with mineralogy and by the operation of the blowpipe. Some varieties of feldspar so closely resemble certain kinds of hornstone, that they can only be recognised by being fusible, which hornstone is not; while many, both of the plutonic and volcanic rocks, are so nearly similar, that a knowledge of mineralogy can alone enable us to distinguish them. We may farther add, that the cautious Germans, who study every science so profoundly, and therefore so successfully, exact from the student at their universities, a due proficiency in mineralogy, before he is allowed to commence the pursuit of geological science.

We have, perhaps, to regret that the first of those departments of knowledge, to which we have to call the attention of our readers, is apparently of an abstruse and arduous character; yet the learner may be assured that its difficulties will, on investigation, be found more apparent than real. It is of course obvious, that a science, a portion of which, crystallography, is based on mathematical induction, must partake, in that department, of the common difficulty of mathematical investigation; but a large proportion of its leading principles and most important elements are perfectly plain and simple, and require, in fact, no knowledge of the mathematics at all. The truth is, it is one of the weaknesses of our nature to be more deterred by apparent than by real difficulties. We see some few mathematical figures, some cubes, squares, pyramids, or prisms; we observe a few mysterious-looking letters, some *a's*, *b's*, *c's*, and *d's* affixed to them; and we are alarmed in a moment, and draw back in affright, fearing that hieroglyphics so strange must contain some deep and hidden mystery, and that studies which require such symbols to express

them, must of necessity be difficult and deterring. The object of the following remarks, and the practical examples which succeed, will be to strip the subject, as much as possible, of its difficulties; and to show that it is no less attractive than other studies of similar kind. Nay its very seeming obstacles will serve to stimulate the researches of the inquiring mind; and the student will speedily perceive that these objects which at first sight may appear unattractive and repelling, are characterized by the same harmony and perfection which belong to all the productions of nature, since they are the work of the same Divine hand which fashions the shell to delicacy and proportion, which moulds the animal frame to symmetry or grace, and adorns the flower with loveliness and beauty!

The following outline of the progress of the science is compiled from various sources, and among others from the History of the Inductive Sciences, by Professor Whewell, to which the student is referred for more extensive details.

The information possessed by the ancients on the subject of minerals appears to have been most scanty and unphilosophical: and the progress made towards a just appreciation of their nature and qualities, in modern times, has been extremely gradual and slow.

Several of those writers who have been mentioned in our brief sketch of the history of geology, are alike honourably associated with that of mineralogy. Thus the celebrated Gessner is honoured as the first who has written on crystallography. Palissy delivered and published lectures on mineralogy at Paris. The work of Encelius, (1557,) though mingled with the follies of alchemy as regards the composition of minerals, is

regarded with approbation, as presenting very judicious views of general classification. Cesalpinus and Schwenkfeld, of Silesia, are eulogized as having published attempts at mineralogical classification, which are regarded as extremely satisfactory for a period when chemistry was so little advanced. Cesius, Georgius, of Stockholm, and Aldrovandus, wrote on the arrangement of minerals, dividing them into earths, solidified fluids, stones, and metals. Their ideas, though often reasonable, are mingled with all the errors of alchemy and the cabala.

Stenson, the Dane, eulogized by Mr. Lyell as a geologist, is noticed as having been the first to observe the constancy of form in crystals; since he remarks in the work already mentioned, which was published in 1669, that though the sides of an hexagonal crystal may vary, the angles are not changed.

Dominic Gulielmini, in a dissertation on salts, published in 1707, not only adopts the same views, observing that, "since there is here a principle of crystallization, the inclination of the planes and angles is always constant;" but Professor Whewell assures us that he anticipates, very nearly, the views of later crystallographers, as to the mode in which crystals are formed from elementary molecules.

These writers were followed by others, who, without achieving any grand discoveries themselves, led the way by their labours to the results subsequently obtained by others, and acted as pioneers in the grand advance which the science was destined to make. Among these are enumerated Cappeller, who published his *Prodromus Crystallographiæ*, in 1723; Bourquet, whose *Lettres Philosophiques sur la Formation de Sels et de*

Cristaux, appeared in 1729; and Henkel, the *physicus*, or naturalist, of the Elector of Saxony, whose *Pyritologia* is dated 1725.

This last writer, though his researches are fettered by his literal interpretation of the Mosaic writings, was extensively acquainted with mineral productions, and has given some valuable information on metallic veins.

Bromel, a French mineralogist, has the honour of being the first (1750) who classified mineral substances, according to their pyrognostic qualities, (those induced by the agency of heat,) in combination with their external characters. Cronstedt shortly after applied a mode of classification previously unknown, to which all the characters of mineral substances were submitted, since he was the first who took into consideration the elementary composition of these objects.

It was reserved, however, for Linnæus to arrange minerals according to their mathematical forms; but though the intuitive sagacity of that great man, observes Professor Whewell, led him to perceive that crystalline form was one of the most definite, and, therefore, the most important of the characters of minerals, he is conceived to have failed in profiting by this idea, because in applying it he did not employ the aid of geometry, but was guided chiefly by what appeared to him resemblances, which, however, were arbitrarily selected and often delusive. His efforts, led to those of a highly successful labourer in the same field, Romé de l'Isle. The great obstacle which lay in the way of these inquirers consisted, as the Professor has observed, in the difficulties presented by the secondary forms of crystals: since in consequence of the apparent irregularities of these forms, arising from the extension or con-

traction of particular sides of the figure, each kind of substance may appear under very different forms; which, however, though apparently dissimilar, are connected with each other by certain geometrical relations. These may be imagined by conceiving a certain fundamental form, to be cut into new forms, in particular ways. Thus if we take a cube and cut off all the eight corners till the original faces disappear, we shall make it an octohedron. This truncation of angles and edges had already been noticed by a writer named Demeste, while the celebrated Werner had published a *Systema Mineralogicum*, in which he had formally spoken of replacement by a plane, an edge, and a point, as methods in which the forms of crystals are modified and often replaced. The wider application of the plan was, however, due to Romé de l'Isle, who in his turn was eclipsed by the celebrated Haüy; who by the variety, extent, and importance of his researches, during a long life, exclusively devoted to mineralogical inquiries, may be regarded as the founder of the school of modern crystallography; those who followed him having taken his views either wholly or in part as their basis. He was the first who successfully investigated the mathematical structure of crystals, taking up the subject where it had been left by Romé de l'Isle. He determined the primary form of every mineral, and showed how the secondary forms were derived, by simple laws of decrement, from the primary form. The knowledge of these primary forms enabled him to arrange the mineral species with more precision than had been done before him. He defined a mineral species to be a substance compounded of the same constituents, united in the same proportions, and possessed of the same

crystalline form. The chief defects of the system of Haüy, as contrasted with the present state of the science, consist first in the unfortunate method adopted by him of imposing a separate name on every secondary crystal, and considering each of those secondary forms as existing by itself, independently of all the rest. This multiplicity of names renders it excessively difficult, it might be said, impossible, to remember all his secondary forms, when they are very numerous, as happens with respect to calcareous spar, sulphate of barytes, iron pyrites, &c.; and the perusal of his book is thus rendered so irksome, that it can hardly ever be undertaken without some specific object. But the grand defect of his system consists in the inaccuracy of his measurements, which were made only by the common goniometer, an instrument not susceptible of giving the angle within half a degree of the truth. After the invention of the reflective goniometer by Dr. Wollaston, which is capable of measuring angles within one minute, the angles of all crystalline bodies were again examined by other mineralogists; and it was found that those assumed by Haüy were very seldom the true ones, differing from the real measurement frequently by several degrees. This general inaccuracy has rendered the measurements and calculations of Haüy of comparatively little value for the science.

It may here be expedient to offer a brief definition of the recent discoveries of those laws of chemistry which have so intimate a relation to the nature and composition of minerals.

Isomerism, which was discovered by Berzelius, is a principle which is somewhat vague and doubtful in its application, but which may be defined as that law by

virtue of which bodies having the same molecular composition, and the same atomic weight, have different physical properties.

Isomorphism, is the law by which an equal number of atoms, combining in the same manner, may give birth to similar crystalline forms, although the constituent elements are of a different nature.

Dimorphism, is a law which, having been previously known, has been confirmed by the discoveries of Mitscherlich. It is considered to be only a peculiar kind of isomerism.

The law of equivalents, is that principle by which bodies combine with each other in constant and invariable quantities.

The law of substitutions shows that constituent elements may be substituted for each other, without producing any change in the nature of the compounds. This law, which is perhaps a peculiar case of the law of equivalents, was fatal to the electro-chemical theory of Berzelius, since it proves that electro-positive bodies may be substituted for electro-negative, and vice versa. Another cause of the ruin of this theory is that it has been acknowledged to be impossible to disengage electricity in placing two bodies in contact, and that it is to their combination with ambient, or surrounding bodies, that we must attribute the electric phenomena which are manifested in most cases. The experiments of Zamboni on the dry pile have demonstrated this truth, so that at present recourse is had to affinity,—a law by which different atoms unite with emission of heat, light, and electricity, electricity being considered in such cases as the effect and not the cause of the combination.

The most important additions, since the period of Haüy, have been effected by the endeavours of Weiss

and Mohs to establish distinct systems of crystallization, founded on essential distinctions of crystalline form. Professor Weiss showed the importance of considering the axes in crystals, and established on these the distinction and classification of crystalline systems; he also published a theory of zones, calculated to facilitate the development of compound forms, which theory has served as the basis of the representatives of crystalline forms to two of his pupils, Neumann and Quenstedt. Professor Mohs gave a new exposition of the principles of crystallography, and published a remarkable classification of minerals, founded solely on their physical and external characters. He was followed by Breithaupt, Haidinger, and Zippe. Neumann proposed a new notation of crystalline forms, much more simple than those of Weiss and Mohs, and published, in 1830, a treatise on crystallography, which is regarded as the most learned and complete work which we possess on the subject.

The principles assumed by the German *savans* have received considerable confirmation from the brilliant optical discoveries of Sir David Brewster. The system of Mohs, in particular, is generally adopted, and, with the discoveries which confirm it, will be explained in a future page. The nomenclature of single minerals, however, proposed by Mohs, from being cumbersome and difficult, has failed, as was to be expected, of being universally received. The two electro-chemical systems introduced by Berzelius are conceived to be imperfect. His first attempt was to class all minerals according to their electro-positive element, and the elements according to their electro-positive rank; but the discovery of isomorphism, and the law of equivalents, virtually annihilated the system. These celebrated discoveries were,

in substance, as above-stated, that certain substances assuming the same crystalline form may be substituted for each other in combination, without affecting the external character of the compound. Hence, since bodies with very different electro-positive elements could not be distinguished from each other, it became impossible to place them in distant portions of the same classification; and by such a discovery the system was virtually destroyed. The second attempt, by the same philosopher, to found a classification on the electro-negative qualities of bodies, is declared by our able English historian of the sciences, to be no more trustworthy; for he observes, if the electro-positive elements are isomorphous, the electro-negative elements are sometimes isomorphous also, and he cites the arseniates and phosphates in proof of his assertion.

As the summary of this brief sketch of the history of the science, it may be stated that the systems hitherto proposed can scarcely be regarded as satisfactory or complete, though we should recommend the reader to study that of Mohs as the theory most extensively received. The present state of our knowledge in this, as in other departments of science, is confessedly imperfect; the labours of the distinguished men whom we have enumerated are to be regarded as approximations to the truth, rather than discoveries of truth itself; and, to borrow the admirable conclusion of that author to whom we are largely indebted for the information here detailed, "The combination of chemical, crystallographical, physical, and optical properties into some lofty generalization is probably a triumph reserved for some future and distant years."

Meantime, it is satisfactory to know, that if the theo-

retical portion of the science still continues uncertain, its practical departments have received considerable extension and improvement. Other philosophers have also promoted, by their discoveries in kindred studies, the progress of this pursuit. The chemical researches of Sir Humphrey Davy have elicited the facts of the metallic bases of the earths and alkalis ; while other inquirers have shown that acidity is not an absolute but a relative quality, and that there are substances which, united to certain bodies, act as acids, and with others become bases. While the invention of the reflective goniometer, by Dr. Wollaston, with the addition of the mirror by Mr. Sang, has brought the measurement of crystals to mathematical minuteness and precision ; the application of the blowpipe to the purposes of mineralogy, by a Swedish *savant*, Andreas Swab, (it having previously been only used by jewellers and goldsmiths,) has alike formed an era in the study ; and this instrument, in such hands as those of Bergman, of Gahn, and of Berzelius, has essentially contributed to perfect our inquiries into the physical and chemical relations of the science.

It may be expedient, before we enter on the further description of the subject, to afford an outline of the general qualities of elementary substances.

The chemist divides all bodies into simple and compound ; the simple being those out of which nothing different from themselves can be obtained ; the compound those which consist of two or more elements. It may be cited, as a fact strongly indicative of the progressive character of chemical inquiry, that the number of known simple substances, which in 1787 was only seventeen, and as recently as 1802 no more than

twenty-eight, is now fifty-five. And if it be objected, that many substances now considered simple may probably be compound bodies, which more perfect instruments, more powerful re-agents, and more successful inquiries, will enable us to discover; it may, on the other hand, be fairly assumed that there are elementary substances yet undiscovered, which the aid of these same advantages may hereafter bring to light.

The elementary bodies at present known may be conveniently classed under the following heads:

Five gases, or vapours—oxygen, hydrogen, nitrogen, chlorine, and fluorine.

Seven non-metallic solids and fluids—sulphur, phosphorus, selenium, iodine, bromine, boron, and carbon.

Three metallic bases of the alkalis—potassium, sodium, and lithium.

Four metallic bases of the alkaline earths—barium, strontium, calcium, and magnesium.

Six metallic bases of the earths—aluminum, silicum, yttrium, glucinum, thorinum, and zirconium.

Thirty metals, whose combinations with oxygen produce neither alkalis nor earths.

1	Manganese	11	Uranium	21	Mercury
2	Iron	12	Columbium	22	Silver
3	Zinc	13	Nickel	23	Gold
4	Tin	14	Cobalt	24	Platinum
5	Cadmium	15	Ceranium	25	Palladium
6	Arsenic	16	Titanium	26	Rhodium
7	Molybdenum	17	Bismuth	27	Osmium
8	Chromium	18	Copper	28	Iridium
9	Tungstenum	19	Tellurium	29	Vanadium
10	Antimony	20	Lead	30	Lantane

Of these metals, the first five decompose water at a red heat. The next fifteen do not decompose water at any temperature, and their oxides are not reducible to the metallic state by the sole action of heat. The oxides of the rest are decomposed by a red heat. It may be added, that of the above there are not more than sixteen elementary substances which have any space of importance in the formation either of the earth itself or the atmosphere which surrounds it, and consequently which possess any especial claim on the attention of the geologist.

These substances are—

Oxygen	Fluorine	Magnesium
Hydrogen	Phosphorus	Calcium
Azote	Silicum	Iron
Carbon	Aluminum	Manganese
Sulphur	Potassium	
Chlorine	Sodium	

Of the above elements, oxygen is the most important, forming part both of the atmosphere and the earth itself, since all the elements can enter into combination with it. For instance, assuming silex to form nearly one-half of the solid part of the earth's crust, silex is ascertained to be a compound substance, of which oxygen forms one-half.

Were these bodies perfectly free to combine with each other, the amount of such combinations would be infinite, and the number of minerals endless; but their combinations are limited by two important laws; the first of which is, that certain substances have so strong an affinity for each other as to combine and prevent combination between others whose affinities are more feeble; while the second law consists in the fact, that

in all bodies which are chemical combinations, and not mere mechanical mixtures, the ingredients unite only in definite and invariable proportions. Thus hydrogen unites only with eight times its weight of oxygen to form water; while this is the lowest proportion in which oxygen enters into combination. The following explanation of chemical nomenclature, extracted from the excellent work of Dr. Turner, will convey not only an explanation of mere terms, but with these of the most important principles of chemistry as connected with mineralogy.

"Chemistry," he observes, "is indebted for its nomenclature to the labours of four celebrated chemists, Lavoisier, Berthollet, Guyton Morveau, and Fourcroy. The principles which guided them in its construction are extremely simple and ingenious. The known elementary substances, and the more familiar compound ones, were allowed to retain the appellations which general custom had assigned them. The newly discovered elements were named after some striking property. Thus, as it was supposed that acidity was always owing to the presence of the 'vital air,' discovered by Priestley and Scheele, they gave it the name of oxygen, derived from two Greek words, signifying a generator of acid; and they called 'inflammable air' hydrogen, from the circumstance of its entering into the composition of water.

"Compounds, of which oxygen forms a part, were called acids and oxides, according as they do or do not possess acidity. An oxide of iron or copper, signifies a combination of these metals with oxygen, which has no acid properties. The name of an acid was derived from the substance acidified by the oxygen, to which was

added the termination *ic*. Thus, sulphur*ic* and carbon*ic* acids, signify acid compounds of sulphur and carbon with oxygen gas. If sulphur, or any other body, should form two acids, that which contains the least quantity of oxygen is made to terminate in *ous*, as sulphur*ous* acid. The termination in *uret* was intended to denote combinations of the simple non-metallic substances, either with one another, with a metal, or with a metallic oxide. Sulphuret and carburet of iron, for example, signify compounds of sulphur and carbon with iron. The different oxides or sulphurets of the same substance were distinguished from one another by some epithet which was commonly derived from the colour of the compound, such as the black and red oxides of iron, and the black and red sulphurets of mercury. Though this practice is still continued, occasionally, it is now more customary to distinguish different degrees of oxidation by derivatives from the Greek. *Prot*oxide signifies the first degree of oxidation; *deut*oxide the second; *trit*-oxide the third, and *per*oxide the highest. The sulphurets, carburets, &c., of the same substances, are designated in a similar way. The combinations of acids with alkalis, earths, or metallic oxides, were termed salts, the names of which were so contrived as to indicate the substances contained in them. If the acidified substance contains a maximum of oxygen, the name of the salt terminates in *ate;* if a minimum, the termination *ite* is employed. Thus, sulph*ate*, phosph*ate*, and arseni*ate* of potash, are salts of sulphur*ic*, phosphor*ic* and arsen*ic* acids; while the terms sulph*ite*, phosph*ite*, and arsen*ite* of potash denote combinations of that alkali with sulphur*ous*, phosphor*ous*, and arseni*ous* acids. The advantages of a nomenclature, which disposes the

different parts of a science in so systematic an order, and gives such powerful assistance, to the memory, is incalculable. The principle has been acknowledged in all countries where chemical science is cultivated, and its minutest details have been adopted in Great Britain. It must be admitted, indeed, that, in some respects, this nomenclature is defective. The erroneous idea of oxygen being the general acidifying principle, has exercised an injurious influence over the whole structure. It would have been convenient also to have had a different name for hydrogen. But it is now too late to attempt a change, for the confusion attending such an innovation would more than counterbalance its advantages. The original nomenclature has, therefore, been preserved, and such additions have been made to it, as the progress of the science rendered necessary. The most essential improvement has been suggested by the discovery of the laws of chemical combination. The different salts formed of the same constituents were formerly divided into *neutral*, *super*, and *sub*-salts. They were called neutral if the acid and alkali were in proportion for neutralizing one another; super-salts, if the acid prevails; and sub-salts if the alkali is in excess. The name is now regulated by the atomic constitution of the salt. If it be a compound of one equivalent of the acid, to one equivalent of the alkali, the generic name of the salt is employed without any other addition; but if two or more equivalents of the acid be attached to one of the base, or two or more equivalents of the base to one of the acid, a numeral is prefixed so as to indicate its composition. The two salts of sulphuric acid and potash are called sulphate and bi-sulphate; the first containing one equivalent of

the alkali, and the second, two of the former to one of the latter. The three salts of oxalic acid and potash are termed the oxalate, *bin*-oxalate, and *quadro*-oxalate, because one equivalent of the alkali is united with one equivalent of the acid in the first, with two in the second, and four in the third salt. As the numerals which denote the equivalents of a super-salt are derived from the Latin language, Dr. Thomson proposes to employ the Greek numerals *dis*, *tris*, *tetrakis*, to signify the equivalents of an alkali in a sub-salt."

The above account of the present system of nomenclature explains the nature of the compound substances, termed acids, oxides, sulphurets, and carburets; and we will now offer a slight explanation of the distinguishing properties of acids and alkalis. Acids are compounds, capable of uniting, in definite properties, with alkaline and earthy bases; and when in a state of solution, they either have a sour taste or redden litmus paper. Most acids contain oxygen as one of their elements, which was therefore supposed, at one time, to be the acidifying principle; but acids exist which have no trace of oxygen, and there are bodies, for instance, water, which contain a large proportion of oxygen, without possessing acid properties at all. Alkalis have a peculiarly pungent taste; neutralize acids; turn some vegetable blues to green; change to a reddish brown the yellow colour of paper stained with turmeric; and restore the blue colour of litmus paper, reddened by the action of acids.

Minerals may be discriminated by their external and their chemical characters, these last being determined by two kinds of analysis, the qualitative and the quantitative, the former being again divisible into examina-

tion by the blowpipe, or the dry mode, as it is sometimes called, and the action of tests and re-agents, or the humid method. Of these we shall confine our attention to the external characters, and the examination by the blowpipe, referring the student for information on those departments of the investigation which have reference to chemistry to the various works on that science, as those of Thomson, Brande, Turner, &c. &c.

CRYSTALLIZATION.—The particles of the liquid and gaseous bodies above enumerated, during the formation of solids, sometimes cohere together in an indiscriminate manner, and give rise to shapeless masses; but they occasionally attach themselves to each other in a certain order, so as to constitute solids possessed of a regularly limited form. Such bodies are called crystals, and the process by which they are formed is termed crystallization. Certain crystalline forms are peculiar to certain substances; and though these forms are modified to a considerable extent, yet we invariably can, by a careful dissection of the crystal, extract from it a nucleus which constantly has exactly the same form in the same mineral species. Thus, whatever be the shape of a crystal of calcareous spar, we can always obtain from it an obtuse rhomboid; while every cube of fluor spar, by cautiously dissecting off the angles, yields for a nucleus a regular octohedron. Such a nucleus is called a primary form, while the secondary forms are deducible from the primary by certain laws of decrement. So constant are these forms, that calcareous spar never crystallizes in cubes, nor fluor spar in rhomboids.

CRYSTALLOGRAPHY.—A crystal may be defined to be

any symmetrical solid contained within plane, or sometimes within curved surfaces.

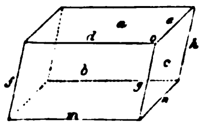


FIG. 4.

These surfaces are called planes, or faces, as *a a*.

An edge is formed by the meeting of two planes, as *d*.

Crystals may sometimes be split in directions parallel to their natural planes, and frequently in other directions.

The splitting a mineral in any direction, so as to obtain a new plane, is termed cleaving it; and the crystal is said to have a cleavage in the direction in which it may be so split.

The planes produced by cleaving a crystal are termed its cleavage planes.

A plane angle is produced by the meeting of any two lines or edges.

The angles *d*, *c*, *e*, *d*, *o*, *g*, fig. 2, are formed by the uniting of the lines *d*, *o*, *o*, *e*, and *d*, *o*, *o*, *g*.

A solid angle is produced by the meeting of three planes.

A plane angle is either an acute, a right, or an obtuse angle; and these will be readily understood by the following explanations and the accompanying figures.

First describe a circle and apportion it into 360 degrees; next draw a perpendicular line *a* ——— *b*, and

a horizontal line *c*———*d*, intersecting each other at the centre, and dividing the circle into four equal parts, each containing ninety degrees.

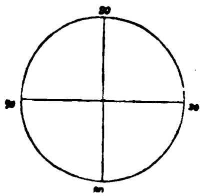


FIG. 5.

If the angle be less than ninety degrees, it is an acute angle; if ninety degrees, a right angle; if more than ninety, an obtuse angle. Thus, in the following figure,

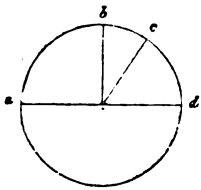


FIG. 6.

a and *b* form a right angle; *b* and *c* an acute angle; *a* and *c* an obtuse angle:—or in another and perhaps simpler form,

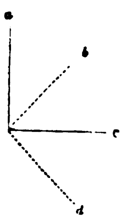


FIG. 7.

a and *b* are an acute angle; *a* and *c* a right angle; *a* and *d* an obtuse angle.

In fig. 2, the plane *a*, and the plane opposite, on which the object is depicted as resting, are called the summit, or the base, or the terminal plane; while the planes *b* and *c*, with those parallel to them, are termed lateral planes.

The edges of the terminal planes, as *d*, *e*, *m*, and *n*, fig. 2, are called terminal edges.

The edges *f*, *g*, and *h*, produced by the meeting of the lateral planes, are termed lateral edges.

The planes of a crystal are said to be similar when their corresponding edges are proportional, and their corresponding angles equal.

Edges are similar when they are produced by the meeting of planes, respectively similar, at equal angles.

Angles are similar when they are equal, and contained within similar edges respectively.

Solid angles are similar when they are composed of equal numbers of plane angles, of which the corresponding ones are similar.

An equilateral triangle, fig. 8, is a figure contained within three equal sides, and containing three equal angles.

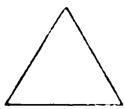


FIG. 8.

An isosceles triangle, fig. 9, has two equal sides, *a b*, which may contain either a right angle, or an acute, or obtuse angle. If the contained angle be less than a

right angle, it is an acute angle; if greater, it is obtuse. The line on which *c* is placed is called the base of the triangle.

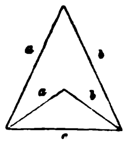


FIG. 9.

A scalene triangle has three unequal sides, and contains three unequal angles.

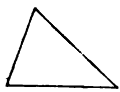


FIG. 10.

A square, fig. 11, has four equal sides, containing four right angles.

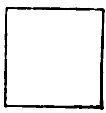


FIG. 11.

A rectangle, fig. 12, has its adjacent sides, *a* and *b*, unequal, the four contained angles being right angles.

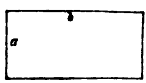


FIG. 12.

A rhomb, fig. 13, has four equal sides, but its adjacent angles, *a* and *b*, unequal.

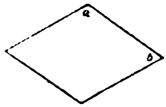


FIG. 13.

A rhomboid differs from a rhomb, in having only two, instead of four, equal sides, as

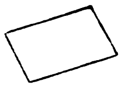


FIG. 14.

An oblique-angled parallelogram, fig. 15, has its opposite sides parallel, but its adjacent sides, *a* and *b*, and its adjacent angles, *c* and *d*, unequal.

FIG. 15.

When certain forms of crystals are described with reference to the rhomb, as the figure of their planes, they are termed rhombic.

A parallelopiped is any solid contained within three pairs of parallel planes.

Crystals often present the appearance of having lost their edges and solid angles, which are then said to be replaced by tangent planes. A tangent plane, with reference to an edge, signifies a plane inclined equally to the two adjacent primary planes, and parallel to the edge which it replaces; or, in plainer terms, it means cutting off the edge so even as to take off as much on one side as the other, as in the cube,

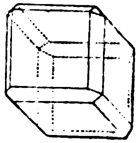


FIG. 16.

or octohedron,

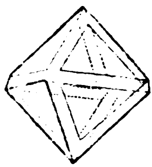


FIG. 17.

and the same description applies to a solid angle.

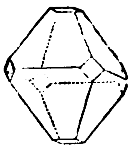


FIG. 18.

When an angle is replaced by two such converging planes, terminating in an edge, like that of a chisel, it is said to be bevilled.

When a solid angle is replaced by three or more converging planes, it is said to be acuminated, that is, it is replaced by planes meeting in a point.

The forms of crystals, as before observed, are divided into primary (also called fundamental or derivative) and secondary, or derived forms. This distinction is founded on the relation of certain geometrical solids to each other; on the transition of one form to another exhibited in many minerals; on the replacement or truncation of

their edges and solid angles, and on the facility with which most crystallized minerals split in certain directions; so that, however various the forms of their crystals, they may all be reduced, by cleavage, into some simpler form, presenting smooth and shining faces, like the natural planes of a crystal.

To exemplify this process, the student has only to take some substance which may be cut with ease, as a piece of soap, or a turnip, and practise these cleavages as follows:—First cut the object into a cube, thus

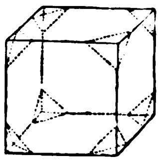


FIG. 19.

Then replace the solid angles; in plainer terms, cut off the corners thus,

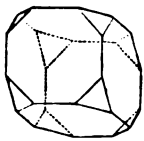


FIG. 20.

Continue the process, (taking care to preserve the layers thus removed,) till the planes of the cube dis appear, and the octohedron will be the result.

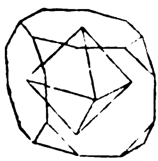


FIG. 21.

Again, if the student cut off the corners of the solid angles of the octohedron, thus,

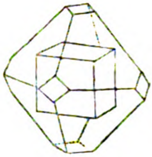


FIG. 22.

and continue to enlarge these planes equally till the faces of the octohedron disappear, a cube will be formed.

Or, if the twelve edges of the octohedron be replaced by tangent planes,

FIG. 23.

and if these be continued till they intersect, the rhombic dodecahedron will be the result.

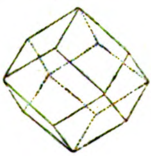


FIG. 24.

By the replacement of the four alternate solid angles, or corners of the cube, till the cubic faces disappear, the tetrahedron may be formed;

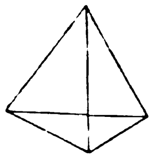


FIG. 25.

and by replacing all the edges of the cube with tangent planes till they intersect, the rhombic dodecahedron, fig. 24, may be produced.

In speaking of the replacement, or cutting off the edges, or solid angles, we do not, of course, mean that these have actually been cut off; for, in fact, they have never existed; but what is meant is, that the same appearances are produced, as if such truncations had actually taken place.

We have purposely recommended the pupil to preserve the slices which he has taken off, in producing the cube from the octohedron, and the octohedron from the cube, because each of these forms being deducible from the other, he will only have to replace them to form the cube on the octohedron by addition, as the octohedron was formed from the cube by diminution; and again, after reducing the octohedron to the cube, he may form the octohedron on the cube by restoring the slices he has removed.

The secondary forms of crystals are conceived to have arisen, from the regular arrangement, on the planes of the primary forms, of layers of crystalline matter, gradually decreasing in breadth, such layers being composed of molecules, so infinitely minute as to be perfectly invisible; so that a pyramid formed of such

particles would present, on its surface, no inequality which would be perceptible to the eye.

FIG. 26.

With regard to the forms of these ultimate molecules, it is known that secondary crystals may be cleaved into layers parallel to the planes of a primary nucleus of a different form, as the cube into the octohedron, as in the case of fluor, &c., while these layers may be divided by cleavage in other directions, so as to afford small bodies of determinate shape, which, divide and sub-divide them as we may, still preserve, as long as they are visible, the same form. These forms, therefore, whether cubes, octohedrons, &c., are considered as those of the component molecules of which these crystals are composed.

The arrangement of the molecules is found to be different in different forms, particularly in the case of the rhombic and pentagonal dodecahedrons. By placing a low three-sided pyramid on each plane of the regular octohedron, a rhombic dodecahedron may be formed, as

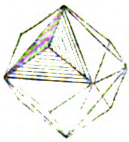


FIG. 27.

The rhombic dodecahedron may also be formed from the cube, by placing a low quadrangular pyramid on each face of the cube, as

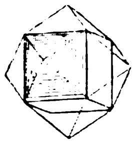


FIG. 28.

The pentagonal dodecahedron may likewise be formed on the cube, by placing, on each of its sides, an equal and similar pyramid, having two triangular and two quadrangular planes.

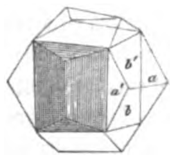


FIG. 29.

It will be seen, that, in the formation of these two different dodecahedrons on the same primary form, the cube, if the molecules, as they doubtless are, be all of the same cubic form, they must be very differently arranged in the two cases; for in the rhombic dodecahedron, fig. 24, the faces are all equal and inclined on the faces of the cube at the same angle; while in the pentagonal dodecahedron, the faces of the pyramid are only equal two and two, *a* and *a*, *b* and *b*, and are inclined on the planes of the cube at different angles. From measurements by the goniometer, and calculations carefully made, for determining the mode of aggregation

of atoms of the same shape, requisite to produce these different forms, it has been ascertained that the pyramids of the rhombic dodecahedron, fig. 24, must be composed of successive layers of molecules, each layer being of the thickness of one molecule, and each successive layer diminishing by the breadth of one molecule on each side; but that in the case of the pentagonal dodecahedron, fig. 29, the layers composing its pyramids must be of the thickness of two molecules, and must diminish in breadth unequally on the two sides; that is, on the side of the quadrangular plane *a*, they must diminish two molecules in breadth, for one in height; and on the side of the triangular plane *b*, they must diminish one molecule in breadth, for two in height, thus,

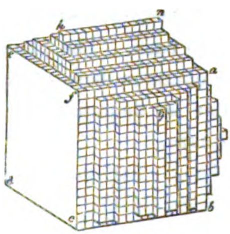


FIG. 30.

Hence, it is inferred that external form depends, as might be supposed, on internal structure, and is determined by the combination of minute particles of regular shape.

We will now submit a list of the primary forms, which, on the authority of Mr. Brookes, are conceived to be in number fifteen, as follows:—

1. The cube, contained within six square prisms.

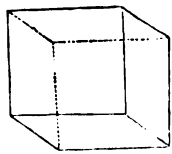


FIG. 31.

2. The regular tetrahedron, contained within four equilateral triangular planes.

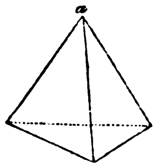


FIG. 32.

3. The regular octohedron, resembling two four-sided pyramids, set base to base. The planes are equilateral triangles; and the common base of the two pyramids, which will hereafter be denominated the base of the octohedron, is a square.

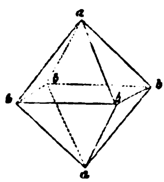


FIG. 33.

4. The rhombic dodecahedron, contained between twelve equal rhombic planes, having six solid angles, consisting each of four acute plane angles, the two opposite ones, as *a* and *b*, being sometimes called the summits, and eight solid angles or corners, consisting each of three obtuse plane angles.

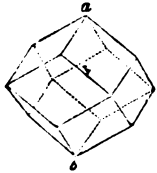


FIG. 34.

5. The octohedron with a square base, which is bounded by eight faces which are similar isosceles triangles. The base, *b, b, b, b,* is always a square, and is the only part of the figure which is constant.

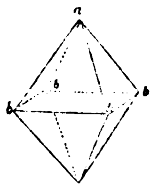


FIG. 35.

6. The rectangular octohedron, which is limited by eight isosceles triangles. The base, *b, b, b, b,* is always a rectangle; but the ratio of its two sides is variable, as are all the other dimensions of the figure.

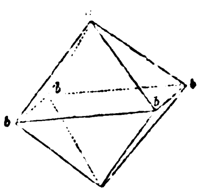


FIG. 36.

7. The rhombic octohedron is contained under eight

faces, which are similar scalene triangles, while the base, *b, b, b, b*, is a rhomb. All its dimensions are variable.

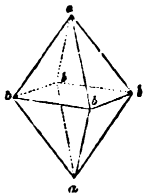


FIG. 37.

8. The right square prism, which is a six-sided figure, differing from the cube only in its four lateral planes, *c, c, c, c*, being rectangles. The extreme or terminal planes, *a, a*, are square. The term, right, denotes that the lateral and terminal planes are inclined to each other at a right angle. It is used in opposition to oblique, which signifies that the sides are not perpendicular, but form an oblique angle with the terminal planes.

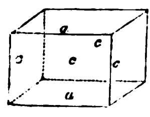


FIG. 38.

9. The right rectangular prism differs from the preceding, in the terminal planes, *a, a*, being rectangular instead of square.

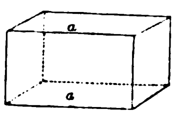


FIG. 39.

10. The right rhombic prism differs from the preceding only in its terminal planes being rhombs.

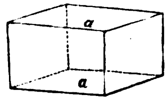


FIG. 40.

11. The right rhomboidal prism differs from the preceding form, in the terminal planes, *a*, *a*, being rhomboids.

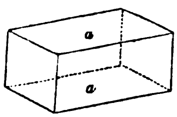


FIG. 41.

12. The oblique rhombic prism; in this form the terminal planes, *a*, *a*, are rhombic, and the lateral planes form an oblique angle with them.

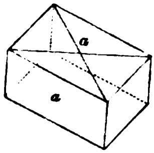


FIG. 42.

13. The oblique rhomboidal prism, sometimes called the doubly oblique prism, differs from the preceding in the terminal planes, *a*, *a*, being rhomboids.

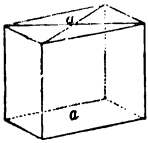


FIG. 43.

14. The rhombohedron, which is bounded by six prisms, which are exactly of the same size and form.

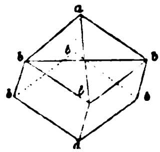


FIG. 44.

15. The regular hexagonal prism, which is bounded by six perpendicular, and two horizontal or terminal planes, which are at right angles to the former. Like the regular hexagon of geometry, the lateral planes incline to each other at angles of 120 degrees. If these angles are not of 120 degrees, the prism is irregular.

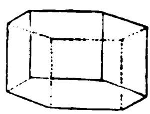


FIG. 45.

These are considered as the primary forms, many of which are geometrically allied to each other. Thus, as we have already observed, if the six solid angles of the octohedron are replaced by tangent planes, and that these are enlarged till they intersect each other, and the faces of the octohedron disappear, a perfect cube is produced.

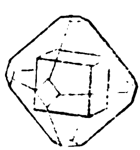


FIG. 46.

If the twelve sides of the octohedron

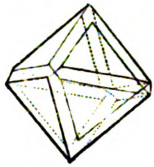


FIG. 47.

are replaced by tangent planes, and these are extended till they mutually intersect, the rhombic dodecahedron will be formed.

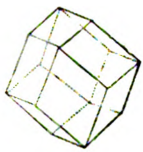


FIG. 48.

The cube may, by analogous changes, be converted into the octohedron, tetrahedron, and rhombic dodecahedron. For, as previously stated, if the eight solid angles of the cube be replaced by equilateral triangles, and these are enlarged till the planes of the original cube are destroyed, the octohedron results.

FIG. 49.

The tetrahedron may be formed by replacing the four alternate solid angles of the cube by tangent planes, so that all its original faces disappear.

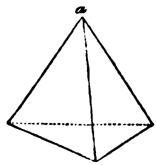


FIG. 50.

By replacing the twelve edges of the cube

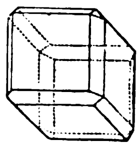


FIG. 51.

with tangent planes till the new faces intersect each other, the rhombic dodecahedron will be produced.

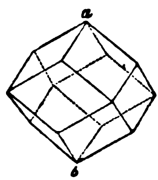


FIG. 52.

The octohedron with a square base is allied to the right square prism, for if

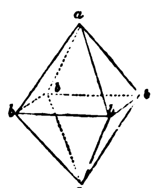


FIG. 53.

two tangent planes are substituted for the solid angles, *a*, *a*, and the edges of the base are replaced by faces perpendicular to the former, new forms will result. If the faces of the octohedron disappear, the right square prism is formed.

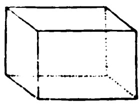


FIG. 54.

If two tangent planes are substituted for the solid angles, *a*, *a*, and the edges of the base are replaced by faces perpendicular to the former, new forms will result. If the faces of the octohedron disappear, the right square prism, fig. 54, is again formed. But if traces of them remain, secondary forms, intermediate between the two primary forms, will be produced.

The rectangular and rhombic octohedrons, and the right rectangular and rhombic prisms, are associated with each other. Thus on replacing the solid angles *a a*, and the four edges of the base of the rectangular octohedron

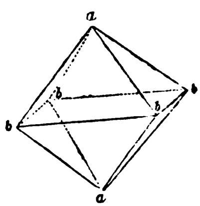


FIG. 55.

by tangent planes, and extending them till the planes of the octohedron disappear, the right rectangular prism is formed,

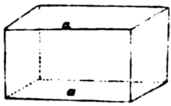


FIG. 56.

and the rhombic octohedron,

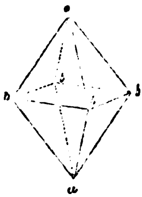


FIG. 57.

by a similar change, is converted into the right rhombic prism.

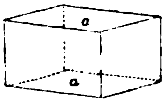


FIG. 58.

By applying tangent planes to all the edges of the rhombic octohedron, fig. 57, except those of the base, the rectangular octohedron, fig. 55, may be produced; and by reversing the operation, the latter is converted into the former. In this last case, the solid angles of the

rhombic octohedron must be so placed as to bisect the edges of the base of the rectangular octohedron.

The rhombohedron, fig. 44, and the six-sided or hexagonal prisms, fig. 45, are allied to each other. If tangent planes are laid on the two solid angles of the rhombohedron, and either the six, solid, lateral angles marked *b*, or the edges between them, are replaced by equal planes perpendicular to the former, a six-sided prism results; and the six-sided prism may be reconverted into the rhombohedron, by replacing all its alternate solid angles by equal and similar rhombic planes.

The six-sided prism is often associated in nature, (for instance in quartz,) with a six-sided pyramid, formed by all its terminal planes, being replaced by isosceles triangles, fig. 9. If the faces of the prism disappear, the double six-sided pyramid results.

Those crystalline forms which have an intimate geometrical connexion with each other, are considered, by crystallographers, as constituting certain groups, which are termed systems of crystallography.

Classification of Mohs.—This arrangement apportions the fifteen primary forms as follows:—

I. The Tessular system comprises the cube,

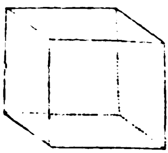


FIG. 59.

the tetrahedron,

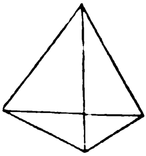


FIG. 60.

the regular octohedron,

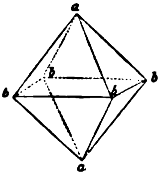


FIG. 61.

and the rhombic dodecahedron, &c. &c.

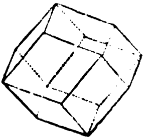


FIG. 62.

The Pyramidal includes the octohedron, with a square base,

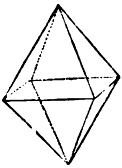


FIG. 63.

and the right square prism.

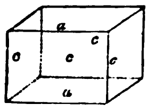


FIG. 64.

III. The Prismatic comprises the rectangular octohedron,

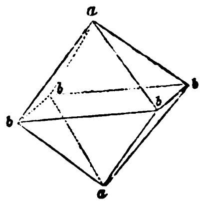


FIG. 65.

the rhombic octohedron,

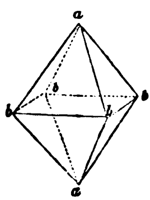


FIG. 66.

the right rectangular prism,

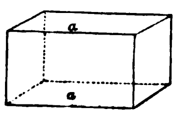


FIG. 67.

and the right rhombic prism.

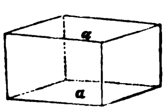


FIG. 68.

IV. The Hemi-Prismatic consists of the right rhomboidal prism,

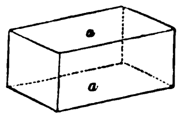


FIG. 69.

and the oblique rhombic prism.

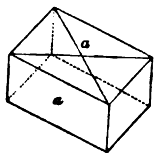


FIG. 70.

The Tetarto-Prismatic is composed of the oblique rhomboidal prism.

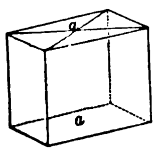


FIG. 71.

V. And the Rhombohedral includes the rhombohedron,

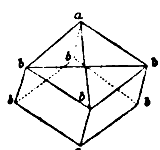


FIG. 72.

and the regular hexagonal prism,

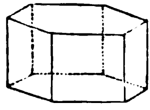


FIG. 73.

Two or more simple forms united together constitute a combination. These combinations are of great importance in the study of crystals. They are called binary, triple, &c., according to the number of simple forms combined.

The combined forms must be derived from one and the same fundamental form. They must be in such positions, with regard to each other, as are peculiar to the system to which they belong.

The edges in which the faces of two different forms contained in a combination meet, are termed edges of combination.

Discoveries of Sir David Brewster.—Such is a brief outline of the arrangement of crystalline forms of Mohs, which is extensively adopted, and the distinctions of which are, at least, so far important and correct, that all the forms which a salt or any substance assumes, almost always belong to the same system of classification. The justice of this mode of arrangement has been farther proved by the optical investigations of Sir David Brewster, which will be best understood by the following explanation.

If we draw a black line on paper, and view it through a piece of Iceland spar, which is the purest variety of carbonate of lime,* the line will appear double in every position except one, in which it will be observed to overlap the other. In the position at right angles to that, the separation of the two lines is the greatest possible. The overlapping takes place in what is called the principal section of the crystal, and the greatest separation occurs in a plane very nearly coinciding with the equator

* See a splendid example in the collection of the British Museum, case 43.

of double refraction, which is a plane at right angles to the crystallographic axis of the rhomboid.

If we cut off the summits of the rhomboid, and polish the new faces, we shall find, that a pencil of light transmitted through these new faces is not divided into two. The line along which there is no double image, is named the axis of double refraction, or the optic axis.

The discovery effected by Sir David Brewster certainly confirms, in a very important degree, the correctness of the arrangement proposed by Mohs. He has ascertained that all minerals belonging to the same system are connected by intimate optical relations; for instance, that all those which belong to the rhombohedral and pyramidal systems, have only one axis of double refraction, which is coincident with the axis of symmetry of the crystal; that all minerals belonging to the prismatic system, and its subordinates, have two axes of double refraction; while all belonging to the tessular system, have either three axes *in equilibrio*, or are otherwise so constituted with reference to this property, that they do not display any double refraction at all.

The above slight and imperfect sketch will suffice to show that crystallography is an extremely interesting and instructive study, and one which can by no means be omitted in an account of the external characters of minerals. At the same time it cannot be denied, that however valuable or attractive to the experienced mineralogist, it is of little practical use in furnishing a guide for discriminating minerals. This is especially the case as regards the beginner, and the practical geologist. Few minerals, comparatively, occur in the state of regular

crystals; they are met with, either massive or so imperfectly crystallized, that the student is compelled to have recourse to other characters, which, when united, are more obvious, though singly they may be less definite than that afforded by the measuring of crystals. Crystallography, it may be said, is to mineralogy what the mathematics are to calculation; while the general characters of minerals may be considered as representing the arithmetic of the science; the former being essential to a complete acquaintance with the study, but being fitted chiefly for the solution of difficult questions, and intricate problems, and more exclusively adapted for the use of the proficient; while the latter and more elementary department is useful for acquiring a general knowledge of the subject, and is more peculiarly adapted for the tyro and the beginner.

External Characters of Minerals.—The next step in the progress of the student will be to render himself acquainted with the external characters of minerals; and with the view of studying these and the practical details of the science, it is essential that he should possess a properly arranged collection; and, if possible, that he should avail himself of the assistance of a well-qualified instructor; since more may be learned in a few lessons from a skilful teacher, than can possibly be gathered from books in a lengthened period. The gentlemen already mentioned, Mr. Heuland, Mr. Sowerby, Mr. Stutchbury, and Mr. Tennant, are in the habit of furnishing collections of this kind. Minerals are also to be met with, advantageously, at the sales of those objects, at Messrs. Stevens's sale-rooms, King-street, Covent-garden. Collections are likewise

supplied by Mr. Abel, of Hamburgh; and Mr. Krantz, of Berlin. The specimens comprising such a cabinet need not be either large, showy, or expensive; they should be arranged according to the system of Phillips; and with the exception of some of the more rare and scarce objects, should comprise the substances enumerated at the close of Phillips's Introduction, (Allan's edition, page lxxx.) It will also be necessary to procure another collection in fragments, prepared expressly for analysis and fusion by the blow-pipe. The works required will be few; that of Phillips should form the text-book, with Griffin's Treatise on the Blow-pipe; Sowerby's British Mineralogy may also be consulted with advantage. The copy of Phillips should be bound with blank leaves, for the purpose of taking notes of the specimens composing the collection of the student, the lessons of his instructor, and the general knowledge which he himself acquires. His specimens should all be registered on the blank pages, so as to point out their proper place in the drawer; thus $\frac{6}{14}$ may indicate that a certain mineral is placed as the fourteenth object in the sixth drawer. They should all be ready labelled; but if not, it will be found an excellent plan to procure some old catalogues of Messrs. Stevens's sales of minerals, for the purpose of cutting out the names, and gumming them on the specimens, a method which will look neater, and take up less space than hand-writing. The student should also possess a set of models of crystalline forms, which can be procured of the parties above-named.

In addition to his own cabinet, he should farther avail himself of the various public stores within his

reach, and, in particular, the splendid collection of the British Museum may be consulted with eminent advantage by the aid of the Synopsis.

The other objects enumerated by Phillips and Griffin, as blow-pipes, spirit-lamps, fluxes, supports, platinum spoon, wire, foil, glass tubes and matrasses, files, knife, hammer, pestle, mortar, anvil, a pocket lens, or Codington, as those instruments are termed, an electrometer, a common goniometer, Wollaston's goniometer improved by Sang; and, in short, every requisite instrument, may be procured of Messrs. Knight and Co., Foster-lane, who have published an extensive catalogue of chemical apparatus; of Mr. Tennant, 149, Strand; and also of Mr. Palmer, of Newgate-street; Mr. Clarke, 428, Strand; and others.

The reflecting goniometer will be found indispensable for correctly measuring the angles of crystals, and, as in the instance of augite and hornblende, for distinguishing several which present considerable similarity to each other. The use of the instrument is not particularly difficult, and the student is referred to Phillips, 4th edition, Introduction, p. xxxii., for directions, the observance of which will speedily enable him to attain the management of it with ease and success.

In studying the characters of minerals according to the arrangement of Phillips, the student should commence by a careful and attentive perusal of the admirable Introduction from page xiii. to page lxviii. The various external characters detailed in page xviii. should be the object of especial study, more particularly those enumerated in the first column in the following list; and the chapter on Structure, above all, cannot be too firmly impressed on the mind.

They are as follows:—

External form.	Transparency.
Structure.	Lustre.
Fracture.	Colour.
Frangibility.	Flexibility.
Hardness.	Double refraction.
Streak.	Touch, taste, and odour.
Magnetism.	Powder.
Electricity.	Adhesion to the tongue.
Specific gravity.	Phosphorescence.

Cleavage.—It may be necessary to add a few remarks on this subject, which is not particularly dwelt on in the work of Phillips. It means the indications of the faces of the primary crystal, or at least of some of them. There are several minerals which possess cleavage so perfect, that they at once exhibit the crystalline faces, by splitting into fragments, having each the crystalline shape of the mineral; as calcareous spar, which breaks into rhomboids, and galena, which divides into cubes. Other minerals require more care; sometimes the natural joint may be seen by turning the crystal round in a strong light; and by the application of a chisel, or a small knife, it may be cleaved in those directions; or it may be split by means of a pair of small cutting pincers, whose edges are parallel. A small, short chisel, fixed, with its edge outward, in a block of wood, is a convenient instrument on which to rest a mineral which we are desirous of cleaving. Minerals, sometimes, cleave only in one direction, as mica; sometimes in two, three, or four. As some practice is requisite, it will be expedient to commence with a facile substance, as car-

bonate of lime, or galena, and proceed to others more complicated and refractory.

The student, when he has gone through this preliminary course of reading, may enter on the practical examination and study of his collection. In so doing, he will find it expedient to confine his attention to a few objects at once; and a single genus, if somewhat extensive, as, for instance, quartz, will afford ample study for the first few lessons.

USE OF THE BLOWPIPE.—Having thus made some acquaintance with the laws of crystalline form, and the system of crystallography, as most generally adopted, as well as with the general characters of minerals, the student should next examine them by means of the blowpipe. His text-book for this purpose should be a cheap and unpretending little work, already mentioned, entitled, "Griffin's Treatise on the Use of the Blow-pipe;" by the guidance of which we venture to assure our reader he will not only acquire the use of that instrument with little trouble or delay, but will soon have no difficulty in satisfying himself of the name and properties of any mineral which may fall in his way. Another work, by the same author, entitled "Chemical Recreations," contains some useful tables of the behaviour, (as it is called,) of minerals before the blow-pipe, the colour of their beads when fused with the various fluxes, &c. &c. The directions contained in these treatises are so simple and judicious, that we shall at once refer to them for farther particulars, and content ourselves with a very few plain and practical observations.

In the first place, we have ever found the plainest and most simple blow-pipe to be the best: the common

curved brass instrument used by jewellers, without a bulb, is what we prefer; and of these we should recommend two, one with a small orifice for the inner, and one with a larger for the outer flame. With reference to the use of the instrument, our own experience tends to convince us that the difficulty of employing it is much exaggerated, and that, in fact, there is very little trouble in the matter. We add, however, the following directions for those who may require them :—

The great object, of course, is to maintain an equal and steady stream of air, as long as is required. To effect this, the beginner should first learn to breathe through the nostrils, keeping the mouth shut; next let him distend the cheeks with the air thus inhaled, and make several respirations without allowing the air to escape from his mouth; when able to effect this, let him put a blow-pipe between his lips, and filling his mouth with air, expel it, gently and steadily, by the action of the cheeks, while he breathes by his nostrils, applying the tongue to the palate, so as to interrupt, in some degree, the communication between the mouth and the nostrils. As the air in the mouth becomes exhausted, it may be renewed by withdrawing the tongue from the palate, and replacing it again, as in pronouncing the syllable *tut.* Let him first practise this with the blow-pipe alone, without applying it to a flame at all; next let him try to keep up a flame without directing it to any object; and lastly, let him attempt to oxidize some of the metals, to reduce some of the most facile ores, and to fuse some of the most fusible earthy substances. Bismuth or galena will answer to begin with; and having practised with a few

others, he may attempt the various substances in the order prescribed in the treatise of Mr. Griffin.

As regards the flame, we should advise him to commence with a candle: one of a substantial size and large wick is to be preferred; such as are called shoemakers' candles, with double wicks, are extremely well adapted for the purpose. As the candle, however, is apt to gutter, from the heat of the charcoal on which the mineral requires to be placed, the student as he advances may use a tinned lamp, which may be fed with oil, or tallow, or naphtha. Alcohol is best, as being clearest, and giving no smoke, but it is of course the most expensive. The wick of the lamp, or candle, it may be added, should be divided, to give the greater extent of flame, and should be bent in the direction of the object to be examined. The orifice of the blowpipe should be held about the tenth of an inch above the bent wick, and the air should be impelled along the wick without touching it. The operator should place the candle in such a position as to be able to rest both elbows on the table. It may be necessary to add, that a gentle and steady blast is quite sufficient, and that beginners commonly blow with too much violence. Should the student still find a difficulty in using the instrument,—which, after the above information, we can scarcely conceive will be the case,—he has only to apply to the first working jeweller at hand, and such a person will be fully able to instruct him.

The blow-pipe is usually placed in two different positions with reference to the flame, which will be best explained by the following figures. The first represents the outer, or oxidating flame.

To produce this, it is necessary to use the blow-pipe

with the larger orifice, and to insert it about the tenth of an inch into the flame, and about the same distance above the wick, while the assay, which is supported on a platinum hook, is held at the point of the flame.

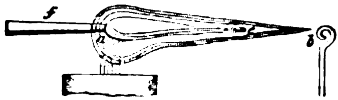


FIG. 74.

The inner, or reducing flame, is managed as follows: the blow-pipe should have a smaller orifice than that employed for the outer, or oxidating flame; it is necessary to blow a little stronger than in the last experiment, and the position of the assay should be such that it is surrounded by flame.

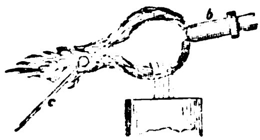


FIG. 75.

The small fragment of a mineral submitted for examination by the blow-pipe is called the assay; and with respect to size, the beginner should not attempt a piece larger than a grain of mustard-seed. It is a common fault to commence with specimens which are too large. It ought, if possible, to be chipped off, in the shape of a small scale, with a sharp edge, or point, because these points are more easily acted on than those which are thicker; and in proportion as the point becomes rounded, or retains its sharpness, it may be considered fusible or infusible. Next take a piece of

charcoal, (that prepared from alder is best,) and, with a borer made for the purpose, make a neat little hole about the eighth of an inch deep, and the fourth of an inch wide, and situate between the centre and the edge of the piece of charcoal. It will be expedient to saw the charcoal into sticks an inch square, and to support them on a piece of tin, bent at the end to hold them firmly.

The preparatory operation, termed roasting, or calcining, consists in submitting the metallic arseniurets, sulphurets, and other substances, to a low, red heat; the supports, that is the substances on which it is placed, being either charcoal, mica, the open glass tube, or the tube with a bulb at the end, called the glass matrass.

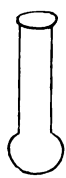


FIG. 76.

Unless this operation be carefully performed, so as to expel all the sulphur or other volatile matter, it will be found impossible to reduce the ore with any satisfactory result.

Fluxes are substances added to metallic ores, or other minerals, in order to promote their fusion. The most useful of these are borate of soda, or borax; carbonate of soda, and microcosmic salt, which should be procured pure, and kept in phials.

The mode of proceeding with the fragment of a mineral to be examined by the blow-pipe is this: first, heat it gently in the glass matrass, observing whether

it give off water, change colour, decrepitate, give off volatile matter, and whether such matter be sulphur, known by its peculiar odour; arsenic, which in smell resembles garlic; selenium, which gives an odour resembling decayed horseradish; or mercury, which is known by its peculiar appearance.

The next progress, will be to heat another fragment of the same mineral, without fluxes, on charcoal; observing whether, on being gently heated in the outer flame, it give off volatile matter, and whether such matter be sulphur, arsenic, or selenium, &c.; whether it decrepitate, become magnetic, fuse, and whether such fusion be complete, partial, quick, slow; with a pasty aspect, or with the appearance of a liquid; whether it intumesce, and that slightly, or violently; whether it volatilize; whether it give off fumes, and whether they be copious or slight; white or of what other colour; whether they leave a remainder or not, and whether they condense, or do not condense on the support. It is also to be observed, whether the assay colour the jet; burn either with or without a flame; change colour once, or more than once; whether it become absorbed by the charcoal; whether it fuse with a result, and whether such result of such fusion be a bead of metal, or ashes, or powder; a glassy globule, or a white enamel; whether the glass be transparent, or filled with air-bubbles; coloured or colourless; homogeneous or heterogeneous; and whether the enamel be smooth, or have the appearance of a frit, or whether it be homogeneous or heterogeneous.

A fragment of the mineral well roasted, to drive off all metallic matters, is then to be heated with the different fluxes, and its behaviour with each noted, observing all the particulars above enumerated, after fusion,

in treating of its behaviour on charcoal alone. The order in which the different appearances take place must likewise be noticed, and whether they occur on the first application of heat, or after long exposure to its action. For earthy minerals, charcoal is not a convenient support; they may be first dried in the matrass; and then a small scale held in the forceps is to be heated, first in the outer flame, then in the inner, in order to try its fusibility. If it should prove refractory after a long application of the inner flame, and if no appearance of roundness on the point or edges of a minute scale or splinter can be discovered through a lens, it may be considered infusible by itself, and may then be heated with soda, on platinum foil, or wire. By this process, fusion will be effected, and the tinge imparted to the glass thus produced will indicate the metallic oxide, which forms the colouring matter of the mineral.

Classification of Minerals.—Mr. Griffin, in his Treatise on the Blow-pipe, already mentioned, divides the minerals into four classes, according to their habits before the blow-pipe, and other characters easy to be ascertained.

The classes comprise

1 Combustible minerals.
2 Metallic minerals.
3 Earthy minerals.
4 Saline minerals.

1. The combustible minerals are distinguished by the following characteristics.

They are of low specific gravity, generally below 2·0, water being as 1·0; none, with the exception of the diamond, being above 2·5, and some so light as to float on water.

They are all (with the exception again of the diamond) soft, yielding easily to the knife; some are liquid.

Some of them are highly combustible, at or below a red heat. The rest are all, more or less, combustible by the action of the blowpipe; even the diamond is slowly combustible at a less heat than is required to melt silver.

2. The characteristics of the second class, the metallic minerals, are,

Specific gravity exceeding 5.

Lustre metallic when scraped.

These are in the metallic state.

Or specific gravity less than 5·0, but more than 2·5, and they are destitute of the metallic lustre, but they are

Reducible to the metallic state by the blow-pipe, or

Rendered magnetic, or

They volatilise wholly, or in part, producing a vapour, or

Communicate a colour to borax.

Some of the substances of this class are combustible, but their specific gravity greatly exceeds that of the combustible minerals of class 1.

3. The earthy minerals are characterised as follows:

Insoluble in water.

Tasteless.

Incombustible at a white heat.

Specific gravity less than 5·0.

They are farther destitute of true metallic lustre when scraped; are not reducible to the metallic state; nor do they volatilise at a high temperature before the blow-pipe.

4. The saline minerals are
Soluble in water, and
Impart a taste.

These classes are divided into orders, and some of the orders into genera, and the genera again into families.

The first class is divided into two orders, characterised by their burning with a flame, or without it.

The second class is also divided into two orders, the characteristics of which are volatising, or not volatising. The first order is divided into genera, distinguished, the first, by volatising wholly; the second, by leaving a residue reducible to the metallic state with borax; and the third, a residue not so reducible.

The characteristics of the families, into which the genera of the first order are divided, are the absence or presence of the metallic lustre.

The characters of the genera of the second order are, the being, or not being, reducible to the metallic state, either with or without borax. The families are distinguished by the absence or presence of the metallic lustre; or by the assay becoming, or not becoming, magnetic after roasting.

The third class, the earthy minerals, are divided into three orders. First, those that are soluble, wholly, or in a considerable proportion, in cold, dilute, muriatic acid. Secondly, those fusible before the blow-pipe. Thirdly, those infusible. The first order is not divided into genera and families. The second and third orders are divided into several genera, the characteristics of which are their different degrees of hardness; and these degrees of hardness are characterised by the minerals, first, scratching quartz with ease; secondly, scratching quartz

with some difficulty, and scratching feldspar with ease; thirdly, being as hard, or harder, than feldspar; being scratched by quartz, and scratching window glass with ease; fourthly, being softer than feldspar; scratching fluor, and scratching window glass feebly; fifthly, being scratched by fluor spar.

The fourth class, or the saline minerals, are divided into two orders, the characteristics of which are, the giving or not giving, when in solution, a precipitate with carbonated alkali. These orders are not divided into genera and families, the minerals composing them being few, and easily distinguished.

For further details, more especially connected with the chemical department of the science, we again refer to the works of Turner, Thomson, Brande, Griffin, &c. By pursuing the various branches of inquiry which we have thus pointed out, by studying first, the principles of crystallography; by investigating, next, the external characters of minerals; and by directing his attention, lastly, to their chemical relations, the student will, by insensible and rapid degrees, acquire a highly valuable acquaintance with this interesting science, and will soon be able to effect the essential objects of identifying the various mineral substances submitted to his inspection, and of connecting their occurrence with the respective deposits in which they occur, and with the general structure and past history of the earth. In short, he will speedily be enabled to acquire a sufficient knowledge of the subject for every purpose of geological investigation.

EXERCISES

ON CRYSTALLINE FORMS.

1. Let the student, as before mentioned, take a piece of soap or a turnip, and cut it into a form resembling the following figure, he will produce a cube, and will thus form the first geometrical figure in the series.

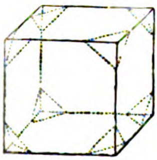


FIG. 77.

2. Cut off the corners regularly and evenly, so as to leave a neat little triangle at each corner, and you will have made an important advance. In scientific terms, you will have replaced the solid angles by triangular planes.

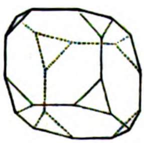


FIG. 78.

3. Continue cutting off the corners till the faces of the

cube disappear, and you will effect another modification; the cube will be changed to the octohedron.

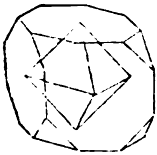


FIG. 79.

4. Cut off the corners of the octohedron, and you will produce the following figure.

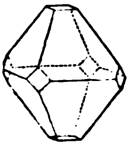


FIG. 80.

And if you continue these cuttings till the faces of the octohedron disappear, a cube will again be formed.

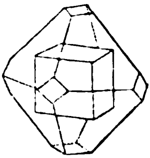


FIG. 81.

5. Form a cube a second time, and cut away its four

alternate corners, till the faces of the cube are destroyed, and you will form a tetrahedron.

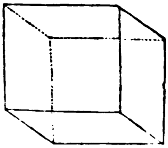


FIG. 82.

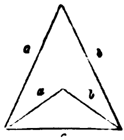


FIG. 83.

6. Form a cube a third time, and cut off its edges evenly and neatly, so as to take off as much on one side as the other, and you will have effected another operation, that of replacing the edges of a cube by tangent planes, as

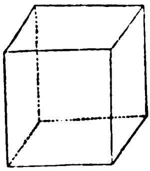


FIG. 84.

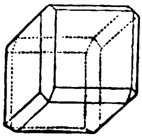


FIG. 85.

7. Continue these cuttings till they intersect, and the rhombic dodecahedron will again be produced.

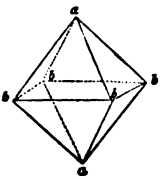


FIG. 86.

8. Form an octohedron, and cut off its twelve edges

in a like even manner, and you will likewise replace its edges by tangent planes.

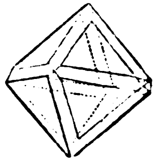


FIG. 87.

9. Continue these cuttings till they touch each other, and you will again produce the rhombic dodecahedron, figure 86.

10. Form a cube a last time, for the following purpose, which has already been mentioned. Cut off the corners very carefully and regularly, and as carefully lay the slices aside till you have formed the octohedron. Then replace the slices on the octohedron, till you restore it to a cube.

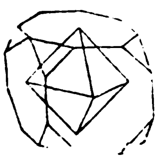


FIG. 88.

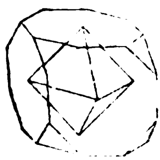


FIG. 89.

11. Form an octohedron for the like purpose, reduce it to a cube, and, by replacing the slices, restore it to an octohedron again, figure 81.

12. Commit to memory the names of the fifteen primary forms, page 157; study their characteristic differences, as well as their geometrical relations; copy their outlines on tracing paper, and study them by the assistance of a series of models.

13. Describe their appropriation in the system of Mohs.

Obs. The figures have in various instances been intentionally repeated for the convenience of learners, schools, classes, &c.

EXERCISES

ON THE GENERAL CHARACTERS OF MINERALS.

1. We would here repeat the recommendation which we have previously urged on the student, viz., to commence by reading with much care the Introduction to Phillips's Mineralogy, and to devote his peculiar attention to the chapter on structure, as well as to the various sections which treat of external form, fracture, hardness, double refraction, and specific gravity.

2. Commit to memory the divisions of mineral substances, as enumerated both by Phillips and Griffin, and learn the chief types of each class.

3. There are some half-dozen different substances which, from their occasional resemblance to each other, should be studied with peculiar assiduity; and the pupil should accustom himself, both in theory and practice, to distinguish between them, both as single minerals, and in their combination in rocks. They are quartz and carbonate of lime, hornstone and feldspar, and augite and hornblende. With a view to this object,

4. Describe quartz under its general physical characters of mineral composition, hardness, fusibility, forms and localities of occurrence, crystalline form, and different species and varieties.

5. Ascertain in what respects quartz differs from crystallized carbonate of lime, and what are its best discriminating characters.

6. Describe carbonate of lime under the heads specified above, and repeat in what particulars it is distinguishable from quartz.

7. Describe, in a similar manner, hornstone and feldspar, and state the points of distinction between such varieties of these substances as resemble each other.

8. Describe augite and hornblende, and state their distinctive characters.

9. The student is farther recommended to pay particular attention to the following mineral substances, as being of frequent geological occurrence, viz., mica, talc, clinkstone, claystone, chlorite, actinolite, hypersthene, diallage, serpentine, steatite, jasper, porphyry, basalt, carbonate of magnesia, bitterspar, dolomite, sulphate of lime, bitumen, oxide of iron, sulphuret of iron, iron and copper pyrites, schorl, garnet, and chiastolite.

10. Commit to memory those minerals which represent the scale of hardness.

11. Select various sets, comprising each some half-dozen familiar substances, and describe their principal characters, as primary form, fracture, colour, transparency, hardness, action of acids, action of blow-pipe, &c. &c.

12. Write out a list of crystalline forms, and copy, on tracing paper, the outlines of such as are most familiar and frequent of occurrence.

13. Copy and commit to memory a list of the zeolites, enumerating their principal varieties and distinctive characters.

14. In exemplifying the above instances, the student

should be careful to unite practice with theory, and to examine every substance by specimens from his own cabinet, with the view to realize the features of the descriptions which he finds in books.

15. After a short period, he may request a dealer to place before him a drawer filled with various but allied species of minerals, and may endeavour to ascertain the names and characters of each.

16. When sufficiently advanced, he may direct a collection of heterogeneous kinds to be placed before him, and may endeavour to identify the names and varieties.

17. At a more mature period he may disarrange the whole of a collection, and endeavour to restore each specimen to its place.

18. For further examples of preparation for investigations by the blow-pipe, the use of tests, and reagents, and of the blow-pipe itself; the student is again referred to the works of Griffin, Turner, Thomson, &c. &c.

CHAPTER VI.

PHYSICAL GEOLOGY.

AUTHORS: HUTTON, PLAYFAIR, M'CULLOCH, BAKEWELL, LYELL, MURCHISON, DELABECHE, &c., &c.

MUSEUMS: GEOLOGICAL SOCIETY, MUSEUM OF ECONOMIC GEOLOGY.

HAVING furnished the preceding elementary information, respecting the substances composing rocks, we will now proceed to offer an outline of the nature and classification of the rocks themselves. The clearest and most comprehensive arrangement which the beginner can form, is by reducing them to that fourfold division, under which they may be classed as follows:

I. After penetrating through the vegetable mould, or alluvium, or drift, or any other local, superficial deposit, the underlying rock, at certain points, is found to be a substance of crystalline, or glassy texture, consisting of one or other of the plutonic or unstratified rocks, comprising granite, with its associate deposits of syenite, greenstone, hypersthene rock, diallage rock, and serpentine; or one of the trap rocks, including basalt, porphyry, clinkstone, claystone, compact feldspar, pitchstone, &c., &c., which are all characterized by the two distinctive features of the absence of stratification and of organic remains.

II. In other localities the crust of the earth, sub-

jacent to the casual accumulations above-mentioned, is formed of volcanic rocks, comprising the lavas, trachytes, basalts, greystones, obsidian, pumice, tufa, &c., the ejection of modern volcanoes.

III. In other places we meet, in the same relative position, with the metamorphic or altered rocks, or primary strata, as they are variously styled, which are conceived to be sedimentary deposits, altered by heat; resembling the plutonic or unstratified rocks in being destitute of fossils, but differing from them in the fact that they present marks of stratification.

IV. At other points we find, in similar situations, the aqueous or fossiliferous strata, which are charactized both by stratification and the presence of fossils.

The foregoing classification is obviously susceptible of being reduced to one of more simple, that is of two-fold kind; for as the rocks of the first two classes above enumerated have been melted, and those of the third altered by the action of fire, while those of the fourth have been deposited by that of water, it results that all rocks may be referred to the agency either of fire or water, it being to these antagonist forces that the Almighty has delegated the task of renewing and perpetuating the solid crust of the earth.

Arrangement of Deposits.—At an earlier period of the science, the arrangement and nomenclature of the rocks, with reference to their order and succession, were determined as follows:

The plutonic and metamorphic rocks bore the general name of primitive, it being conceived that they were formed before all others. The deposits lying immediately above them, from resembling the schistose rocks below, in their crystalline texture, while they bore a similarity

to the sedimentary substances above, in exhibiting proofs of mechanical origin, and containing organic remains, were conceived to form an intermediate class, and the name of transition rocks was employed to distinguish them. The succeeding strata, up to the chalk, were termed secondary, and all above the chalk were named tertiary formations. The progress of geological inquiry, however, soon brought facts to light, which compelled a considerable change in this nomenclature. It was found that the primitive rocks so called were, in fact, of various ages; that some had been erupted as late as the close of the secondary, and others during the tertiary period, having penetrated and altered strata of that date. It was discovered that the so-termed transition strata were, in like manner, of various geological dates and characters, and the result has been the adoption of the arrangement now generally received, by which the primitive rocks, as they were previously termed, are distinguished as plutonic, or unstratified, and metamorphic, or stratified; while the term transition is virtually abolished, and the whole series of fossiliferous deposits, from the earliest, up to the chalk, are termed secondary; the inferior beds up to the carboniferous series being sometimes styled the lower; those from the carboniferous system to the oolite, the middle; and the wealden and chalk, the upper; the strata which overlie the chalk, being named tertiary; while the loose and superficial beds of sand, loam, and gravel, are denominated modern alluvium; and, as these last in some districts are strewed with boulders, and masses of primary rock, such deposits, with some others, are termed ancient alluvium; the beds of gravel, &c., being conceived to be the result of agencies still in operation, while

the drift and boulders are regarded as the effect of violent floods or inundations which have ceased to act on our globe. These subjects of drift, or till, as it is locally termed, and erratic blocks or boulders, have recently engaged considerable attention, and an opinion is fast gaining ground that the erratic substances in question are the results of an agent now in operation, and that they have been transported by icebergs which, on melting, have deposited them at the bottom of the then existing sea. M. Agassiz, as before mentioned, has suggested the glacial theory, as accounting for these deposits; but this hypothesis is scarcely received with so much favour as the preceding; while, in either case, the introduction of ice, as a moving power, constitutes a new and striking feature in geological inquiry.

ARRANGEMENT OF THE STRATA.

FOSSILIFEROUS DEPOSITS.

The following table will convey a general idea of the various formations, as regards their chief and distinctive features of order of succession; mineral composition; and characteristic fossil remains.

I. Alluvium, modern and ancient; the term *modern* being applied to the deposits now in course of formation, or appertaining to the historic period, comprising beds of rivers, lakes, peat-bogs, coral-limestones, volcanic ejections, calcareous deposits from mineral springs, &c., containing the remains and the works of man; the latter appellation of *ancient* being usually bestowed on like accumulations formed prior to the historic era, and containing no vestiges of the human race.

THE TERTIARY FORMATIONS.

II. A vast accumulation of various deposits, marine, lacustrine, fluviatile, and volcanic, containing marine exuviæ, shells of the lake, river and land; plants and remains of mammalia of extinct and existing species.

SECONDARY FORMATIONS.

III. The Chalk, or Cretaceous Group.—A marine series of deposits, including strata of limestone, sandstone, marl, and clay, abounding in marine organic remains, plants, corals, echinodermata, mollusca, crustacea, and fish, with turtles and reptiles.

IV. The Wealden Formation.—A singular and unique interpolation of fluviatile strata, among the marine formations of the secondary period, being the delta of an ancient river, and comprising beds of sandstones, limestones, and clays; containing land-plants, fresh-water mollusca, and fish; tortoises, turtles, crocodiles, and enormous reptiles, the iguanodon, hylosaurus, cetiosaurus, megalosaurus, &c., &c.

V. The Oolite.—A series of marine strata, of enormous extent; comprising limestones, sandstones, and clays, replete with marine mollusca, corals, shells, fish, and reptiles, terrestrial plants, and two species of mammalia, of the marsupial order.

VI. The Lias.—A group of marine argillaceous limestones, marls, shales, and clays, with marine mollusca, crinoidea and fishes; wood and plants, and enormous reptiles, chiefly of the genera ichthyosaurus and plesiosaurus.

VII. The *Poikilitic, or variegated, or salife-

* From ποικιλος, variegated.

ROUS GROUP.—A marine formation, including marls, sandstones, limestones, and conglomerates frequently of red, and occasionally of variegated hues, containing gypsum and rock-salt, with corals, mollusca, plants, fish, and batrachian reptiles.

VIII. THE CARBONIFEROUS SYSTEM, OR COAL.—Consisting of shales, clays, ironstone, sandstone, mill-stone-grit, and limestone, interstratified with seams of coal, containing fresh water, and marine mollusca and fish, and innumerable remains of terrestrial and aquatic plants of tropical types, but of extinct genera and species. The mountain limestone, with some beds of shales, sandstones, and inferior coal.

IX. THE DEVONIAN, OR OLD RED SANDSTONE SYSTEM.—A marine formation; consisting of red and green marls, concretionary limestones, called cornstone, conglomerate, tilestone, micaceous and grey sandstones, green slates, and sandstone, and blue crystalline limestone, containing corals, mollusca, and fish.

X. THE SILURIAN SYSTEM.—An extensive series of marine deposits; comprising limestones, sandstones, grits, flag-stones, shales, and slates, containing corals, mollusca, crustacea (trilobites), and fish.

XI. THE CAMBRIAN SYSTEM.—A marine formation, comprising vast beds of slate rocks, with dark-coloured limestones, and sandstones, containing two or three species of corals, and of brachiopodous mollusca.

XII. THE CUMBRIAN SYSTEM.—A like extensive series of deposits, obviously of sedimentary origin, but in which no organic remains have been discovered.

THE PRIMARY STRATA.

XIII. THE MICA-SCHIST.—Composed of mica and

quartz, interlaminated so as to present the appearance of stratification, but containing no organic remains.

XIV. THE GNEISS.—Formed of the component parts of granite; mica, quartz, and feldspar, fine-grained and laminated, so as to present the appearance of having been produced by the abrasion of granite, and then deposited in water. Both the gneiss and mica-schist are conceived to have been altered by heat, subsequently to their deposition.

THE PLUTONIC, OR UNSTRATIFIED PRIMARY ROCKS.

XV. THE GRANITE AND TRAPPEAN ROCKS.—Comprising granite, syenite, greenstone, hornblende, diallage, serpentine, &c.; together with basalt, porphyry, clinkstone, claystone, and the trap rocks, the whole being alike destitute of stratification and of organic remains.

The relative thickness of each of these several deposits has been estimated as under, but the statement must be regarded as a mere approximation, and the probability is that, with reference to the lower beds, the thickness is much greater than is here mentioned.

Tertiary System . . .	2,000 feet.
Cretaceous	1,100
Weald	1,000
Oolite and Lias . . .	2,500
Saliferous	2,000
Carboniferous	10,000
Old Red Sandstone . . .	10,000
Silurian	7,500
Cambrian	20,000
Cumbrian, at least . . .	10,000

Primary unascertained, but far exceeding that of any of the superposed deposits.

Geological Deposits of Great Britain.—A mere glance at the physical geography of our island will reveal to us its varied and favourable geological condition, and will show that it presents a regularly descending scale of deposits, affording every geological production best adapted to supply the wants and stimulate the energies of mankind.

To commence with the most recent, the tertiary system, we find these deposits occurring in the Isle of Wight, and the adjacent counties of Hampshire and Dorsetshire; they appear in the metropolis and its vicinity, the valley of the Thames, comprising the entire county of Middlesex, with portions of Essex, Kent, Surrey, and Sussex; they re-appear in the crag of Norfolk and Suffolk, and are traced in Yorkshire, and in part of Scotland. The chalk succeeds, occupying portions of Sussex, Surrey, Kent, Hants, Dorset, Wilts; and dipping under the valley of the Thames, occurs north of London, in the counties of Hertford, Bedford, Buckingingham, Oxford, Norfolk, Lincoln, and York. The local deposits of the weald fill up the interval between the chalk hills of Surrey and Sussex, known as the North and South Downs, and appear, to a slight extent, in Wiltshire. The oolite system follows, and commencing with the Isle of Portland, pursues a devious and winding course through the heart of England, from our south-eastern to our north-western shores; proceeding through the counties of Dorset, Wilts, Berks, Gloucester, Oxford, Rutland, Northampton, Lincoln, and York, where it terminates in the vicinity of Scarborough. The lias succeeds in order, and commencing at Lyme Regis, in Dorsetshire, follows a similar and uneven course, in the same direction, through the

counties of Dorset, Wilts, Berks, Somerset, Gloucester, Warwick, Leicester, Nottingham, and Lincoln, into Yorkshire, where it is traced to the sea-coast, and the cliffs of Redcar, near the mouth of the Tees. The new red sandstone, the succeeding member in the series, commencing in the vicinity of Exeter, and pursuing a similar direction through the midland districts; traverses the counties of Devon, Somerset, Warwick, Stafford, Nottingham, Lancashire, Cheshire, and Cumberland, where it gives place to slaty rocks, of older date. The magnesian limestone, an associate deposit, is developed from the Trent to the Tyne, in the counties of Nottingham, Shropshire, York, Westmoreland, and Durham. The coal formation, the next in the sequence, follows no regular course, but is distributed in local areas, called basins, from their forms. The principal, commencing with the south, are those of Somersetshire, Gloucestershire, North and South Wales, Worcestershire, Staffordshire, Warwickshire, Leicestershire, Derbyshire, Nottinghamshire, Lancashire, Yorkshire, Cumberland, Durham, and Northumberland; and in Scotland, those of the Forth and Clyde, with others in various parts of Ireland. The old red sandstone is developed in Devonshire, Herefordshire, Monmouthshire and Shropshire; and in Caithness, Cromarty, and other parts of Scotland. The Silurian, the succeeding term in the order, occurs in Gloucestershire, Worcestershire, Staffordshire, Herefordshire, Shropshire, Radnorshire, Montgomeryshire, Caermarthenshire, Breconshire, Pembrokeshire, and Monmouthshire. The Cambrian and Cumbrian systems consist of masses of sub-crystalline and slaty rocks developed in the county of Cumberland and in Wales, and the mica-schist, gneiss and granite forma-

tions occur in the Highlands and western isles of Scotland and in Ireland; the whole series forming, with one or two trifling omissions, a complete epitome of the physical geography of the whole earth, and in the comparatively limited extent of a few hundred miles, comprising such deposits, and bestowing such blessings, as in other and less favoured regions are only to be met with, spread over extensive continents, and much larger areas of the surface of the earth.

We shall now proceed to give a general idea of the varied deposits under the same fourfold classification to which we have already alluded.

First Class. The Plutonic or Melted Rocks.—Granite.—Granite is a compound, crystalline rock, composed, when in its regular form, of crystals of mica, quartz, and feldspar, which are aggregated confusedly together, so as to interfere with the form of each other, and to be separable by mechanical means. The mineral which generally predominates so as to give its own hue to the rock, is feldspar, which is most commonly dark red, or white; quartz, which is the prevailing substance next to feldspar, and has a proportionate share in determining the colour of the mass, is usually white or grey, and occasionally almost black. Mica, when black, imparts that hue to the rock, but when, as frequently occurs, it is brown or white, it gives those tints to the substance; while the admixture of hornblende, which is dark green, or black, produces a rock varying between these shades. It is evident, therefore, that a substance, consisting of various minerals, themselves of different hues, and mingled in different proportions, must be correspondingly diversified in tint, and thus we have granites of almost all

hues, red, white, black and grey: the most prevalent being white, which is the tint presented by that of Cornwall; or red, which is the colour chiefly exhibited by the Scottish varieties. A striking example of each kind is exhibited in immediate juxta-position in Waterloo-bridge, where the coping-stone is of the red, while the balustrades are of the white variety. There are other substances which enter into the composition of granite, as chlorite, talc, actinolite, steatite, cleavelandite, compact feldspar, &c.; but specimens of this nature, are, comparatively, rare of occurrence, and limited in extent, and are to be considered as exceptions to the rules which we have mentioned above, as generally regulating the composition of the rock.

Granite occurs as the foundation-rock on which all the others repose, while it rises to the highest elevations and loftiest pinnacles on our globe, constituting, as it were, the skeleton, or framework to which all the other deposits are attached. It is, however, obvious, that the substances which yield the materials of the trap and volcanic rocks ejected to the surface, must lie far below the granite. Granite likewise occurs in the state of beds of irregular shape, among strata of gneiss and other ancient stratified deposits. It is also met with in veins, intruding into rocks of all ages, from those granitic injections which are found to penetrate masses of granite older than themselves, up to similar intrusions into the latest secondary, and even the tertiary strata. It has been discovered in the Pyrenees, penetrating into a rock of the same date as the chalk; syenite, which is little other than a variety of granite, has been found overlying the chalk at Weinböhla, in Saxony, as well as in the county of Antrim, in Ireland; while Mr.

Darwin has observed, that the granite of the Cordilleras of South America has been fluid as recently as the tertiary period, and has altered and contorted strata of that date and character. Granite veins are often found intersected by veins of granite, still newer than themselves, and the rock occasionally occurs as dikes, which are, in fact, similar ramifications on a larger scale, the essential difference being that the dikes continue for a longer distance, while the veins thin out and are lost in filaments and threads. Indeed it may be stated, that every mass of granite which forms the central peak of a mountain-chain, is no other than a dike on an enormous scale, which has burst through the superincumbent strata, and borne them upwards in its elevation. While granite is conceived to have generally been erupted in a fluid condition, instances occur in which it has obviously been protruded in a solid state. The proofs of this latter circumstance are afforded by the absence of any dikes, veins or filaments ramifying into the surrounding rocks, as well as by the presence of conglomerates and breccias resulting from the grinding and attrition of such rocks by the elevation of the granitic mass. The chief British localities of granite are, in England; Cumberland, Cornwall, and Devon; in Scotland; the Highlands and the Isle of Arran; and in Ireland; the Mourne mountains.

Syenite.—This is granite in which mica is replaced by hornblende, which gives a darker hue to the mass. Its name is derived from the city of Syene, in Upper Egypt, where it largely abounds.

Greenstone.—This term is applied to those rocks which are composed of feldspar and augite, or hornblende. It is closely allied to syenite, differing fre-

quently only in the preponderance of hornblende over feldspar, and the grey or greenish hue thus induced. They frequently pass into each other, and the celebrated head of Memnon, (or rather of Rameses), in the British Museum,* affords a striking instance of this transition, the body being of greenstone, and the head of syenite, though the whole bust is composed of one continuous mass.

In hypersthene rock, the feldspar is compact or crystallized, and sometimes vitreous, and of a red or white colour. Serpentine is composed of diallage with magnesia; diallage rock, of diallage and feldspar; both are frequently associated with greenstone, and pass into that substance.

THE TRAP ROCKS.—These have already been mentioned as deriving their name from a Gothic term for a stair, or terrace, because they occur in tabular masses, rising one above another, like terraces, or stairs. They comprise the porphyries and basalts in all their varieties of composition and aspect. The name of porphyry is derived from a Greek word, signifying purple, from a variety of this stone, which was used by the ancients for ornamental purposes, being of this colour; though, in reality, its hue was red, rather approaching to crimson than the tint which we designate as purple. It is now applied to any rock having a compact base, in which distinct crystals, generally those of feldspar, are embedded, and is usually indicated by the name of its base, as feldspar-porphyry, which is by far the most prevalent, claystone-porphyry, pitchstone-porphyry, &c., &c.

BASALT.—Basalt is a term now restricted to masses

* See the Vignette in the title page.

of hornblende or augite, which contain titaniferous iron, and in which crystals of feldspar are visible. It has a greenish or brownish black colour, is difficult to break, and possesses a considerable degree of hardness, but yields to the knife. It occurs both in horizontal tabular masses, and in dikes; and exhibits, in both conditions, the varieties of columnar, globular, vesicular, and amygdaloidal structure. In overlying masses, the columns are usually vertical, in dikes they are frequently horizontal. The celebrated experiment of Mr. Gregory Watt would tend to prove, that the columnar structure of basalt arises from the pressure of numerous spheroids on each other, in the act of cooling. This gentleman, as is well known, fused seven hundred weight of Dudley basalt, called the Rowley rag-stone, maintaining the fire for six hours, and allowing it to cool so slowly, that eight days elapsed before it was removed from the furnace. The mass was of a wedge-like shape, four feet and a half long, two feet and a half wide, eighteen inches thick at one end, and four at the other, an inequality of form admirably adapted for exhibiting the different rates of cooling, and the various kinds of texture thus induced. Where the mass was thinnest, and the cooling most rapid, the texture was vitreous or glassy; where it was thickest, and the cooling slowest, the structure became stony, while the intermediate parts exhibited a transition from one state to the other. Numerous spheroids had been formed; where two came in contact, they were compressed, and when several met they formed prisms. We may form some idea of the arrangement, if we conceive a number of cannon-balls to be piled on each other, and then to be reduced to a nearly fluid condition, when the pressure of these globular bodies on each other

would produce a columnar arrangement, similar to that observable in basalt.

Basalt is frequently vesicular, and contains small cavities, caused by the escape of gas or vapour, while the rock was in a fused condition. These have been filled with infiltrations of carbonate of lime, agates, and zeolitic, and other minerals. As these nodules have in general an elongated shape, similar to an almond, such basalts are termed amygdaloidal, from the Greek word for that object. Basalt, like porphyry, is conceived to have been ejected, in many instances, from fissures in the bed of the ocean, and to have flowed over the strata there deposited. The chief localities for these rocks in the British isles are, in England, the vicinity of Durham and Dudley, and in Scotland, the Highlands and the neighbourhood of Edinburgh.

Second Class. The Volcanic Rocks.—We have already alluded to the similarity between these productions and the primary unstratified rocks, as being sufficient, in itself, to prove the igneous origin of the latter, many of them, especially those of the basaltic kind, being so nearly identical as to render it scarcely possible to distinguish between the two.

Volcanic productions are of so compound a nature, and exhibit varieties of combination so numerous and minute, as to require a separate treatise for their description. The reader is, therefore, referred for this object, to the work of either Dr. Daubeny, or Mr. Poulett Scrope, on volcanoes. As a general account it may be stated, that they are usually divided into trachytic and basaltic lavas. The former derive their name from a Greek word, signifying rough, from the roughness of their surfaces; they are of a light earthy colour, and

feldspar is usually an essential element in their composition. The basaltic varieties contain a considerable proportion of iron, the feldspar being replaced by other minerals, as leucite, and they are of dark ferruginous aspect. Mr. Poulett Scrope adds a third class, which from being neither decidedly trachytic, nor decidedly basaltic, from frequently containing both iron and feldspar, and from being of a tint between the two, he denominates greystones. The other volcanic productions are obsidian, or volcanic glass, produced by a rapid rate of cooling; pumice, which is, in fact, volcanic froth, produced by the access of steam or vapour to the mass when in a fluid condition; and aqueous lava or volcanic mud, caused by the admixture of torrents of rain, or of melted snows, which accompany these eruptions, and which, as they consolidate, form rocks of earthy aspect, called tuff or tufa. These substances frequently pass into each other, and both pumice and tufa constantly exhibit transitions into obsidian. As a general idea of the products of active volcanoes, it may be conceived that all lava is, essentially, composed of the same elementary fluid substances, and that its subsequent character and appearance are occasioned by the different agencies to which it is subjected. If cooled rapidly, it becomes a glass; if slowly, a rock, more or less crystalline, in proportion as its rate of refrigeration is more or less quickened; while the presence of gas and its extrication in cooling, leaves it a light and cellular mass.

Cause of Volcanoes.—The primary cause of these phenomena is among those problems, the solution of which appears to be reserved to a more advanced state of our knowledge. From the great quantity of gaseous

vapour evolved during eruptions, as well as from the general proximity of volcanoes to the sea, with other facts of like nature, water is conceived to be an active agent in producing these phenomena, and the two hypotheses which have been proposed to account for their origin, both have reference to aqueous action, as having a considerable share in their production. The first ascribes volcanic eruptions and earthquakes to the effects produced on a heated nucleus, mechanically disturbed by the access of water; the other explains the phenomena by conceiving the decomposition of water to be effected by means of alkaline metals, existing in the interior in an uncombined state. The latter hypothesis, which was proposed by Sir Humphry Davy, soon after his celebrated discovery of the metallic bases of the earths, was subsequently abandoned by him, but has since been revived by Dr. Daubeny. Much may be said on both sides, and while the latter supposition is considered to be more accordant with chemical causes, the former is conceived to be supported by the mechanical phenomena of the undulating movements commonly associated with earthquakes and volcanoes. In the mean time, it is conceived that the co-existence of these causes is by no means impossible, and that a nucleus, in a state of fusion, may contain various metals in a metallic state.

Similarity of the Ancient and Modern Igneous Rocks.—In taking a general review of the plutonic and the volcanic rocks, it is impossible not to perceive such points of similarity as serve to demonstrate their common origin, and prove them all to be vast portions of melted matter which have been poured out at various times, and under different circumstances, from the

interior of the earth. We have alluded to the similarity existing between the products of modern volcanoes and the ancient plutonic rocks, as affording numerous and valid proofs of the igneous nature of both, and the beginner may select from the mass the following, as the most plain and convincing of these facts.

1. They both bear, in many instances, a close resemblance in mineral composition, many of the ancient basalts, as already stated, being scarcely to be distinguished from the productions of existing volcanoes.

2. They alike contain mineral substances and crystals in such abundance, as to constitute the chief source whence these objects are derived.

3. They graduate into rocks of like nature and origin with themselves; thus granite passes through syenite and greenstone into basalt, and this last to pitchstone, in a manner analogous to the transition of modern trachyte and basalt into obsidian or volcanic glass.

4. They intrude into other rocks, and calcine and alter them at the point of contact, converting coal into coke and anthracite; shale, into mica-schist, or flinty slate; and beds of sandstone into quartz-rock, in so striking a manner that it is possible to trace the effects from the very point of meeting, and to note the passage from the altered to the unaltered rock. The same result, under varied conditions, is alike recognised in modern volcanic productions.

To enumerate the whole of those facts which might be adduced to prove the identity of the plutonic and volcanic rocks, would rather burthen than assist the memory of the student; and the few proofs above-

mentioned, with others which will suggest themselves, will amply suffice to show the affinity of both.

General Characters of the Igneous Products. —In quitting this description of the rocks formed by fire, we would recommend the student to adopt the following as the best and clearest mode of simplifying them, and impressing them on the recollection.

1. The granites and their associate rocks, have been formed under conditions of subterranean character, and have melted, cooled, and solidified under the depth and pressure of the earth.

2. The trap-rocks, the porphyries, clinkstones, and basalts, are to be regarded as submarine, and as having been melted, and become cool and solid beneath the depth and pressure of the sea.

3. The volcanic rocks are sub-aerial, and have melted, grown cold, and solidified near the surface, and with access of the atmosphere.

Finally, these productions are, in fact, so identical, that it is by no means unphilosophical to suppose that plutonic, trappean, and volcanic rocks, may all be simultaneously forming at the present moment, and that the same volcano which ejects lava and scoriæ from its summit, may, in its internal abysses, at enormous depths and under vast pressure, be elaborating granite; while, from a neighbouring vent, beneath the adjacent seas, it is spreading its waves and terraces of trap over the floor of the ocean.

Third Class. The Metamorphic Rocks, or Primary Strata.—From the examination of the plutonic and the volcanic rocks, we pass to the consideration of these deposits, which, according to the views now

generally entertained, were originally deposited as the sediments of water, but have subsequently been altered by subterranean heat.

GNEISS.—Gneiss may be termed stratified, or slaty granite. Composed of the same elements, mica (or hornblende,) quartz, and feldspar, it differs from that rock, which presents no appearance of stratification, in this distinctive character, that some of its component minerals, usually the mica and hornblende, are arranged in layers, so as to give a slaty aspect to the mass. The stratification is irregular and contorted, and the dimensions of the strata are variable. When the gneiss is associated with granite, it approaches to the character of that substance; and when the two come in contact, it is scarcely possible to distinguish between them. It is connected with the other primary strata, in the following modes. By the disappearance of feldspar, it passes into mica-schist; by the prevalence of quartz, into quartz-rock; and of hornblende, into hornblende-schist. As regards geological position, it reposes on granite, and is succeeded by the other primary strata, frequently alternating in large masses with one or other of these. In Great Britain it occurs in the Western Islands, and North-west Highlands of Scotland.

MICA-SCHIST.—Mica-schist may be regarded as gneiss, deprived of its feldspar, being a crystalline compound of mica and quartz united in different proportions. It has a laminar structure, which is more or less perfect, according to the proportion and mode of arrangement in which the mica enters into its composition. Its colour is determined by the quantity of the same mineral which it contains, and as that substance varies in tint from white, to dark brown, or black, the

quartz being usually white or colourless, the prevailing hue of the rock is, therefore, grey. Like the rest of the primary deposits, it graduates into other members of the same series, descending by the admixture of feldspar into gneiss, and ascending by the preponderance of quartz, into quartz-rock. In geological position it follows the gneiss, and is succeeded by various schistose or slaty rocks of crystalline texture, frequently passing into some of these. Its chief British localities are the North-west of Ireland, and the Scottish Highlands, especially the picturesque district termed the Trossachs.

The subordinate rocks occurring among the primary strata, may be studied in detail, in some work exclusively devoted to such a subject; as, for example, Dr. M'Culloch's Western Isles of Scotland, and his Classification of Rocks. They are chiefly of schistose or slaty texture, and are formed by the substitution of one mineral for another, which constitutes the characteristic ingredient of the rock.

Thus, chlorite-schist is composed of the mineral substance termed chlorite and quartz, differing from mica-schist, by its dingy, green aspect, and soapy feel. It graduates by the addition of feldspar into a variety of gneiss, by that of mica into mica-schist, and occasionally assimilates with argillaceous slate.

Talcose slate is composed of talc and quartz. It differs from mica-schist, and chlorite-schist, chiefly in the presence of talc, and in its colours, which are leaden, dingy white, or green. It occurs associated with the rocks described above, and passes, by various gradations, into all.

Hornblende-schist is considered to include all hornblende rocks, together with greenstone and greenstone-

slate, whether these rocks possess a schistose structure or not.

Quartz-rock is a substance which offers so many variations of mineral character and aspect, that no single description can well define it, and the reader is referred to Dr. M'Culloch's Classification for more ample and complete details.

Crystalline, or primary limestone, also presents considerable diversity of texture, ranging from the pure or saccharine variety, so termed from its resemblance to loaf-sugar, which is employed as statuary marble, to a coarse, impure, and cherty limestone.

The student should procure a collection of well-defined specimens of these various primary and volcanic rocks. They may be obtained of the parties already mentioned.

FOURTH CLASS. THE FOSSILIFEROUS DEPOSITS.—Having briefly described the unstratified rocks, and the non-fossiliferous strata; having alluded to the most striking proofs of the fused or melted character of the former, and the metamorphic or altered nature of the latter; and having given an outline of the volcanic substances, it only remains to offer some observations illustrative of the fossiliferous strata. These are divided into so many distinct and well-defined groups, as above described, that the learner will speedily be able to identify them, and to describe their chief and most characteristic features. He will be best able to effect this object by considering them under the different heads of mineral composition, order of succession, and embedded fossils; for though neither of these characteristics is, in all cases, to be relied on by itself, yet when viewed in combination, they will be found to afford complete evidence of the relative date and character of

these deposits. Of the proofs thus furnished, that which is derived from organic remains is considered the most decisive; rocks which are extremely dissimilar to each other in mineralogical and lithological characters, having been identified by evidence of this nature. Professor Agassiz has discovered fossils of the chalk in deposits of totally different mineral texture and aspect; while Mr. Murchison has identified the carboniferous limestone in Russia, by its embedding the characteristic shells of that formation in rocks of the colour and appearance of white chalk. And, though we must beware of carrying the generalization too far, or of conceiving that the presence or absence of any particular genus or species is alone sufficient to determine the perfect similarity of rocks situated in regions distant from each other, yet it is obvious that when large groups of fossils are found to be identical, they may be conceived to identify those rocks, however remote, or otherwise distinct from each other, in which they respectively occur.

Characteristic Fossils.—These may be defined to be such organic remains as, being discovered in any given deposit, are also found in every locality where such deposit occurs. They will be readily understood from the foregoing and subsequent observations.

Mineral Veins.—These exist throughout the primary, lower secondary, and even in some cases in the tertiary deposits; but they are far more frequent in the first two of these classes of rocks. They present various peculiarities, many of which the present state of our knowledge scarcely enables us to explain. Near the surface they are usually poor in the metal they contain, become richer at certain depths, and poor again

in lower situations. They also change their metal at different distances from the surface, and the same vein, in Cornwall, has been known to contain zinc above, and copper in great abundance below; while there are mines in the south of France which contain iron above, next silver, and lastly, copper. They are divided into two kinds; those which are contemporaneous with the rock itself, and are conceived to have been formed by the separation into one point of the metallic particles of the surrounding mass, and are therefore termed, by Professor Sedgwick, veins of segregation; and those which comprise the regular metalliferous lodes, which are considered to have been cracks and fissures, caused during the elevation and disturbance of the rocks, which have been subsequently filled up by metallic substances. The phenomena of mineral veins still constitute problems of very considerable difficulty, the full solution of which must, in fact, be left to a more advanced period of our information. For the present it may content the beginner to be acquainted with those well-ascertained facts which have been established respecting them, and the farther consideration of the general question may be reserved for future inquiries. The first point to which we allude, is their evident connexion with igneous rocks and axes of disturbance, the richest mineral districts all over the world being situated in the proximity of these causes; while among others, is their evident connexion with electro-magnetism. While the foreign chemists, Becquerel and Mitscherlich, have succeeded in producing crystals by electricity, Mr. Crosse, of Somersetshire, has obtained calcareous spar from water which was percolating through a limestone rock, and was forming crystals at the place where it was thus

procured: the same experimenter also produced crystals of quartz. The mode by which these remarkable results were effected was highly interesting and instructive; the electric apparatus being extremely small, but being kept in operation for a long period; the very mode in which, according to the opinion of our most enlightened observers, the like results are effected in nature. It is, therefore, confidently assumed that the difference of substances found in certain veins, and their comparative richness and poorness, have all been the consequence of different electric states in the rocks in which they are deposited. Much light has thus already been thrown on the nature of these phenomena; and more information is anticipated from observations of like character.

The Gases.—We have alluded, in a previous portion of this work, to the great share which the gases take in the formation of the crust of the earth, and the vast preponderance of oxygen in rocks, consolidated or unconsolidated, accessible to man. Not only does it combine with all the separate elementary substances, and in particular with the whole of those enumerated in page 140, as constituting a large portion of the crust of the earth, but it also forms twenty per cent. of the atmosphere, and one-third, by measure, of water. Hydrogen contributes the remaining third of this latter substance. It is also emitted from volcanoes, and exists largely in coal. Nitrogen forms four-fifths of the atmosphere, and enters into the composition of animals, living and fossil. It is also a constituent of coal. Carbon is extensively diffused; it forms the principal part of coal; it exists in the state of carbonic acid, in a minute degree, in the atmosphere; and forms alike an important portion of all carbonates.

It is an essential element in vegetable structure, and is produced wherever vegetable or animal matters are undergoing decomposition. Chlorine occurs chiefly in the sea, in rock-salt, and springs of brine. Fluorine exists in most rocks, but in a minute proportion. Phosphorus is extensively diffused throughout the rocks, but its proportion is extremely minute. It is, however, abundant in osseous and other organic remains. Sulphur is found chiefly in the sulphurets and sulphates, which are very extensively disseminated.

Almost the whole of the simple substances above-mentioned have entered into their present combinations as binary compounds; that is, they were united two and two, to form the substances in which they now occur. The following constitute nearly all the binary compounds of the accessible parts of the globe:—1, silica; 2, alumina; 3, lime; 4, magnesia; 5, potassa; 6, soda; 7, oxide of iron; 8, oxide of manganese; 9, water; 10, carbonic acid.

It is calculated that oxygen constitutes fifty per cent. of the ponderable matter of the globe, and that the crust of the earth contains forty-five per cent. of silica, and ten or twelve of alumina. Potassa contributes only seven per cent. of the unstratified rocks, but forms a considerable ingredient in many of the stratified order. Soda occupies nearly six per cent. of some basalts, and other less extensive unstratified deposits, and enters largely into the composition of the ocean. Lime and magnesia are disseminated almost universally among the rocks, in the form of silicates and carbonates; the carbonate of lime having been estimated to form one-seventh of the crust of the globe. Iron, in some binary combination, such as an oxide, sulphuret, or

carburet, constitutes at least three per cent. of all known rocks; and manganese is also widely disseminated, but its quota is extremely minute, not approaching to one per cent. It has often been cited as a fact, which the present state of our chemical knowledge does not enable us to explain, that silica predominates largely in the unstratified, and carbonate of lime in the stratified deposits.

The mass of rocks is composed of not more than some eight or nine simple minerals. These are, 1st, quartz; 2nd, feldspar; 3rd, mica; 4th, hornblende; 5th, carbonate of lime; 6th, talc, comprising chlorite and steatite; 7th, augite; 8th, serpentine; 9th, iron. Other minerals, which either form rocks of small extent, or enter so largely into their composition as to modify their character, are the following:—sulphate of lime, diallage, chloride of sodium (common salt), coal, bitumen, garnet, schorl, staurotide, epidote, olivine, and pyrites. A few of these minerals exist in masses so large, as to be denominated rocks; as quartz, carbonate of lime, sulphate of lime, salt, coal, and pyrites; but in general some two, three, or four are united to constitute a rock, as mica, quartz, and feldspar, to produce granite.

The following general remarks descriptive of some of the peculiarities of rocks, both singly and in groups, may be advantageously borne in recollection.

Extent of the Older Formations.—The oldest and deepest deposits are the most extensive, both in area and in thickness, and diminish gradually as they approach to the more modern formations. It may be added, that in the older and more crystalline rocks we find convincing evidence of the universal action of

fire; and that as we proceed upwards, the traces of this agency become gradually more feeble, till in the upper deposits, with the exception of local sites of extinct volcanic action, we lose all vestiges of its influence.

DERIVED CHARACTER OF THE SEDIMENTARY FORMATIONS.—The sedimentary deposits are all of secondary nature, produced by the degradation and destruction of rocks still older than themselves: thus, among other instances, it may be mentioned that the sandstones of the coal are extremely micaceous; occasioned, of course, by the mica contained in the primary strata from which they are formed; the new red sandstone is considered to be produced from the detritus of rocks of like metamorphic character, and to owe its hue either to the mica or hornblende which those deposits contained. The disintegration of rocks of the primary class is also conceived to have yielded many of the argillaceous deposits and beds of clay appertaining to later formations, while the chalk, in a similar manner, has furnished the chief materials for the formation of the tertiary strata.

SIMILARITY OF CONTIGUOUS DEPOSITS.—It has been remarked as a circumstance of some interest, (since a corresponding analogy is found to prevail, to a considerable extent, in other phenomena of nature,) that a character of transition seems to prevail among many contiguous rocks, and that the lower members of one formation are observed to resemble, in a very striking manner, the upper deposits of the series below. Among other instances of this kind, the inferior beds of the greensand frequently offer a striking resemblance to the superior strata of the wealden formation; while the lower members of the oolite, and the upper deposits of

the lias, are, in many cases, scarcely to be distinguished from each other.

It is a circumstance also worthy of observation, that the lower members of any given geological formations, while they resemble, in lithological texture and aspect, the strata above, usually present in their zoological features, and their organic remains, a closer affinity with the deposits lying below them. Thus, with regard to the fossils of the magnesian limestone, the lowest member of the new red sandstone series; the fish bear, in the heterocercal character of the tail, a nearer resemblance to the fossil remains of the coal formation beneath, than to those of the new red sandstone above; while those of the upper beds of the lower division of the Silurian system present a closer relation to the types of existence which are found in the rocks beneath, than in those occurring above them.

Absence of Strata.—We have already observed, that the succession of the beds, though never inverted, is occasionally imperfect; and that certain members of the series are, not unfrequently, deficient. This result may have been produced by one of two causes; either by the strata having been removed, subsequently to their deposition, by denuding action, or by their never having been deposited in these spots. The former agency, that of denudation, is perfectly clear and obvious; the latter may require some explanation. The disturbances which the crust of the earth has undergone have been so varied, powerful, and extensive, that, it is conceived, no portion of its deposits now occupies its pristine position; and in many districts it is concluded that the strata have undergone oscillation, similar to that of a board balanced on a fulcrum. In the instance,

therefore, of a missing series of deposits, we have only to imagine a movement of this nature, and to conceive that a portion of a given district has undergone submergence, and become the bed of the ocean, while an adjacent part has been elevated so as to form dry land; and we shall immediately perceive that the former has never received those marine deposits which have been accumulated on the latter; and shall thus be enabled to account for the greatest conceivable difference in the mineralogical and zoological characters of strata which lie contiguous to each other.

Drift.—This subject has already been alluded to under the head of ancient alluvium, when it was observed, that the origin and deposition of the drift constitute problems of very considerable difficulty, fitted rather for the researches of the proficient, than for the inquiries of the beginner. It may be useful here to state, that drift is usually classified into two kinds: that which has originated from local sources, and contains pebbles, boulders, &c., derived from the peculiar formation in which it occurs; and that which has been transported from older deposits, and is formed chiefly of fragments of primary, or, at all events, of older rocks. The most important accumulations of drift in this country are divided into three: the first, the Silurian, which overlies the district of that name, and is of local origin, consisting of fragments of the rocks of that formation; the second, a mass which extends southward from Lancashire, over Cheshire, Staffordshire, Worcestershire, Leicestershire, and other of the midland counties, and is composed of fragments of the crystalline and trappean rocks, which constitute the mountains of Westmoreland, Cumberland, and part of Scotland; while the third com-

prises the various deposits of this nature which strew our north-eastern coasts, the shores of Yorkshire, Lincolnshire and Norfolk, as well as the adjacent districts far inland, with fragments of rocks analogous to those now existing no nearer than Scandinavia, and furnished either from that region, or from land which once occupied the present bed of the German ocean.

ARENACEOUS DEPOSITS.— Sandstone is an aggregation of grains of sand; that is, of minute particles of quartz, which is silex in its purest form. Sandstone is usually cemented by a substance of like nature with itself, or, occasionally, the cement is of the nature of lime, clay, or iron. When sandstone is of extremely coarse grain, it is termed grit.

ARGILLACEOUS DEPOSITS, OR CLAYS. — The substances comprehended in the term clay, scarcely admit of a general description; but most of them agree in possessing an earthy texture, and emitting an argillaceous odour when breathed on. They consist of silica, with a variable proportion of alumine, and a small quantity of lime or magnesia. The term is also extended to all kinds of indurated mud, derived from the decomposition and abrasion of various rocks.

POSITION OF ARGILLACEOUS DEPOSITS.—It has frequently been mentioned as a fact of some interest, that the lower beds of many formations are of the nature of clay. This is peculiarly the case in the oolitic deposits, as well as in those of the lias, and others; and, in the opinion of the author, is probably to be attributed to the fact, that the alluvial cliffs, or shores, then in existence, being the first which yielded to the action of the waves, provided materials for the earliest strata deposited in the waters; while rocks of firmer and

more resisting texture yielded more slowly to the abrading force, and furnished, at a later period, the material for those arenaceous and calcareous deposits which occupy higher positions in the series.

CALCAREOUS ROCKS.—This term comprehends all the vast series of rocks of which lime forms a prevailing element, including all the limestones so called, and the marbles, which, it may be observed, are limestones sufficiently hard to receive a polish. It is perfectly easy to ascertain whether a rock be calcareous or not, by applying either muriatic, nitric, or sulphuric acid, and observing if it effervesce. The first of these substances, diluted with water, is the most efficacious; and for the purpose of using it, the student should provide himself with a bottle, to the cork of which a small stick is affixed, which is immersed in the diluted acid, and, on applying this to the stone, if the latter be calcareous, it will immediately effervesce; if it be siliceous, no effervescence will take place. The mixture of sand and clay is usually termed loam, and the combination of calcareous matter and clay is called marl; but both these expressions are employed in a vague and general sense, and are applied to substances of very dissimilar kinds.

STRUCTURE OF SLATY ROCKS. — There are three distinct forms of structure, which are frequently all present in rocks of this nature: the first being stratification; the second, joints; and the third, slaty cleavage; the last two having no connexion with true stratification. The first of these, stratification, will be sufficiently understood after our previous remarks on the subject; the joints are natural fissures of various sizes, from mere cracks to open chinks, which often

traverse the rocks in straight and well-defined lines; while slaty cleavage consists of those lines or partings which are presented by these rocks, and which form the point at which the stone may be readily divided. Joints, Professor Sedgwick states, are distinguishable from slaty cleavage, by the fact, that the rock intervening between two joints has no tendency to cleave in a direction parallel to the planes of the joints; whereas, a rock is capable of indefinite subdivision in the direction of its slaty cleavage. As the origin of joints and that of slaty cleavage still constitute problems of considerable difficulty, on which geologists and mathematicians are by no means agreed, and which the present state of our knowledge can scarcely entitle us to decide, it may be sufficient for the beginner to be informed, that as these characters are only observable in rocks of crystalline texture, and are most strongly defined in such as are ascertained to have been acted on by heat, we are justified in inferring, that heat has been the chief cause of these results, under whatever conditions it may have operated; and, as a general view, it may be considered that slate rocks have been originally deposited in horizontal, or nearly horizontal planes, and that the action of heat has been such as to obliterate these planes, and substitute minute vertical divisions in their stead.

Breccia.—This name is commonly applied to those substances which consist of sharp, angular, unworn pebbles cemented into a mass.

Conglomerate.—This term is usually bestowed on concretions of a similar kind, but in which the imbedded fragments are rounded and waterworn.

Group.—This name is generally applied to a series of

rocks of the same mineral composition and geological character, while a combination of several groups is called a formation; but these terms, as well as those of system and series, are frequently employed, for the sake of avoiding repetition, to indicate any connected suite of deposits, particularly those, the component members of which are varied and dissimilar in texture and aspect.

DELTA.—This name, which was originally bestowed on the deposits formed by the Nile at its mouth, which present the triangular form of this letter of the Greek alphabet, is now applied to all accumulations deposited at the mouths of rivers, whether of this precise shape or not.

DEGRADING AND ELEVATING CAUSES.—We owe to Professor Playfair the observation, which, however, appears from the foregoing pages to have been no new discovery on his part, that there are two opposite forces continually in operation on the crust of the globe, which he describes as exercising the one, a destructive, and the other a conservative influence; the one consisting in the liability of all rocks to be disintegrated and worn, and carried away; and the other, in the capability of the materials which they have furnished to be again elaborated into new strata, by cement, either of calcareous, siliceous, or ferruginous nature; by the action of water, of fire, or of meteoric causes. These various agencies chiefly resolve themselves into what have been called, degrading and elevating powers.

DEGRADING FORCES.—These are chiefly of atmospheric, fluviatile, or oceanic nature. The agency of the atmosphere, of its vapours, and its rain, is twofold—chemical and mechanical: the chemical action consisting

in their absorbing oxygen and carbonic acid from the atmosphere by rocks, and their dissolution by such absorption. By this means, rocks of all classes are speedily weathered, and, to a certain extent, worn away. While these are the chemical results of atmospheric agency, its mechanical effects consist in the fissuring and cleaving rocks by frost, and in its abrading and carrying off the solid earth by the action of rills, brooks, and streams, which, when swollen to floods, or collected as rivers, exercise so powerful and destructive a force, that it is conceived dry land could not long exist, and all would be swept into one vast flood, but for the counteracting agency of antagonist power, in the tendency of these abraded materials to be formed into new strata, and to become hardened into solid deposits, either by the cementing influences already named; by the agency of heat from below; or by the pressure of superincumbent materials.

Elevating Causes.—As the degrading powers are occasioned by water, so the elevating causes are chiefly owing to fire. They may be regarded under the several aspects of the rapid action of volcanoes and earthquakes, and the slower agency of gradually uplifting forces. The operation of volcanoes is too familiar to require any lengthened explanation. Geologically speaking, the action of a volcano is to raise earthy substances from a low to a higher level. It often effects the most sudden and important changes, and produces a hill on land, or an island in the sea, in a single night. It frequently upheaves the solid strata over a vast area; and the coast of Chili, along a line of a hundred miles, and extending from the shore to the Andes, was raised many feet

by the earthquakes of 1822. Similar elevations are traced as having occurred in various localities, during the early ages of the earth.

The existence of a gradually elevating power, which elevates the land, slowly and almost imperceptibly, above the water, has been ascertained by the gradual rise of the shores of the Gulph of Bothnia, the northern coast of Sweden, of Denmark, and other parts of Scandinavia, as determined by Mr. Lyell; and of the south of Italy, as ascertained by Professor Niccolini, of Naples.

Again, sands are deposited on sea-shores, and are borne inland, where they form extensive accumulations, and overwhelm considerable tracts of land. If these sands are saturated with water containing an infusion of lime, they become converted into sandstone.

Among other instances in the British Isles, the ancient town of Bannow, in Ireland, called the Irish Herculaneum, has thus been buried in sand. The *Armoricain*, of Brest, of the 18th of February last, also states, "that recent gales of wind have displaced a mountain of sand, on the coast of Crozon, near Brest, and exposed to view the remains of a village, and a church, surrounded by a churchyard. The oldest inhabitant of the country," adds the journalist, "does not recollect having ever heard of the existence of this maritime Pompeii."

In addition to these mechanical causes, there are vital agencies, which are mainly instrumental in the production of new deposits. The coral insect is perpetually at work beneath the waves, constructing its reefs, and carrying them up to the surface, where they constitute new islands, and by the junction and

union of these, form fresh continents and spheres of habitation for future races of animated beings.

Best Idea of a Geological Formation.—It is, perhaps, scarcely possible to convey to the beginner a more complete and faithful idea of a geological formation, than to conceive that an existing sea, such for instance as the Pacific, were at this moment, by the elevation of its bed, changed to dry land, since we should thus witness all the varied and interesting phenomena observable in the formations of the earth, and in the mineralised beds of its primeval seas. At those points where its largest rivers discharge their waters into the ocean, we should find deposits of silt and mud analogous to the finely laminated clays or marls of our ancient strata. Its calcareous springs would, in numerous instances, cement many of the deposits strewed over its floor to the consistency of stone, and would convert its fragmentary corals and broken shells to beds of limestone and of marble. At other points, we should meet with coral reefs and isles, corresponding with the analogous phenomena of the medial and lower formations of the secondary series of strata. Beds of gregarious mollusca would offer a resemblance to similar accumulations in the ancient deposits; while the various tribes of sponges, zoophytes, shells, crustacea, and fish, would occupy their respective localities, the sponges and corals inhabiting beds and reefs, the shells frequenting the sands of the shore, the crustacea being attached to solid rocks, and the fishes strewn over the floor of the ocean; while the picture would be completed by the exhibition of volcanic agency, exerted both above and below the surface of the waters. Indeed, with the exclusion of the remains and the works

of man, his drowned mariners, and buried fleets, we should find a southern ocean of the present day, if changed to dry land, to present a perfect panorama of the most extensive and important formations of the ancient earth, and of the varied and instructive phenomena of primeval nature.

INVESTIGATIONS INTO THE STRUCTURE OF THE EARTH. —Every section of the crust of the earth, whether natural or artificial, whether caused by the operations of nature, or wrought by the hand of man, affords some insight into its structure, the former being by far the more ample and instructive of the two. While the operations of art may to some extent afford information; while a mere pit or a quarry; a cutting for a railroad or a highway; or even the digging a well or a foundation for a house, may yield some addition to our knowledge; nature herself is her best interpreter; and in her cliffs, whether inland or marine; in her mountain-precipices, escarpments, gorges, and ravines; in the banks of rivers and of streams, the sections of the earth's crust thus exhibited reveal, in the most important and instructive manner, the causes and the nature of its formation.

THE STRATIFIED ROCKS.—In thus investigating the crust of the earth, we find that the natural division of the rocks is into that of the stratified and unstratified deposits. A stratified rock may be defined to be one whose upper and lower surfaces are parallel to each other; in other words, which exhibits that division into layers and partings, which is recognised in every aqueous deposit, every quarry of limestone, and every pit of chalk, as in the accompanying illustration.

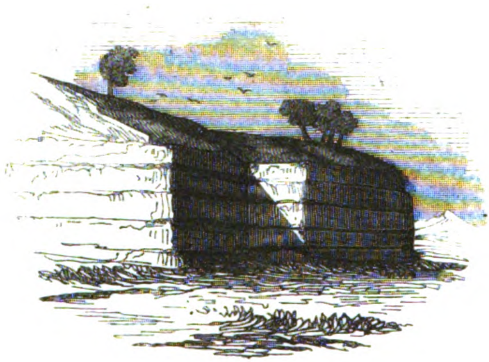


FIG. 90.

Horizontal Position.—These stratified rocks were, doubtless, originally deposited in a horizontal, or a nearly horizontal position, as here depicted,

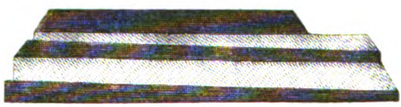


FIG. 91.

agreeably to the law by which fluid substances find their level; and the fact, if it needed farther proof, is demonstrated by the circumstance, that the fossils are always deposited conformably to the planes of stratification. This circumstance is beautifully exhibited in the cliffs of Alum Bay, where rows of flints and silicified sponges, which were originally deposited in a horizontal direction, are now lifted quite upright, together with the beds of chalk which contain them.

DISTURBANCE OF THE STRATA.—Subsequently to their deposition, however, the strata have, in many instances, undergone every variety of disturbance, and have been raised at various angles with the horizon.

VERTICAL STRATA.—Occasionally they are lifted almost to a vertical position, and placed nearly upright, as in the following illustration, from the admirable work of Mr. Murchison, on the Silurian System, exhibiting the strata on which Powis Castle is built.

FIG. 92.

INVERTED POSITION.—In some cases, by the intrusion of igneous rocks, they are actually inverted, and turned back, as instanced in the Malvern hills, from the same publication.

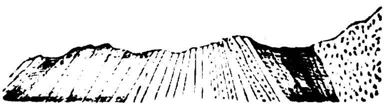


FIG. 93.

DISJOINTED STRATA.—The following figure, from the same work, presents a similar instance of change in the direction of the strata, produced by a like cause, and displayed in the same region. Beds which at *b* strike in a southerly direction, on reaching the Malvern syenite at *b** are thrown into vertical and disjointed masses.

FIG. 94.

Curved Strata.—In other instances they are curved, as is the case with the gneiss, at Oreby, Isle of Lewis, a delineation of which forms the frontispiece to Dr. M'Culloch's Western Isles.

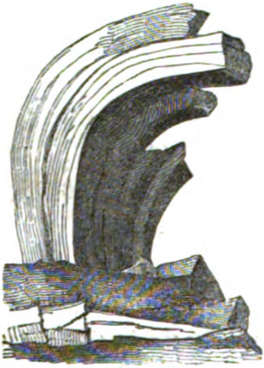


FIG. 95.

Arched Strata.—They sometimes form an arch, as is alike observed by Mr. Murchison, in the Malvern hills; and similar appearances are observable in the dislocations of the strata of Alum Bay, Isle of Wight.

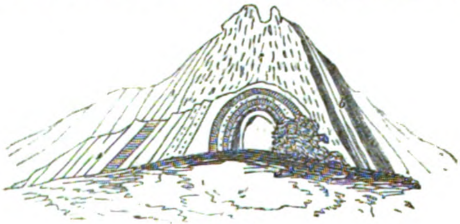


FIG. 96.

CONTORTED STRATA.—Occasionally they are contorted, as remarked by the same observer in another instance, on the banks of the Wye.

FIG. 97.

EXPERIMENTS OF SIR JAMES HALL.—Such contortions were shown by Sir James Hall, by means of a simple but ingenious experiment, to have arisen from lateral pressure, attended with some degree of resistance, both above and beneath. He took various pieces of cloth—some linen, some woollen—and placing them horizontally on a table, *c*, covered them by a weight, *a*, acting horizontally on the pieces of cloth.

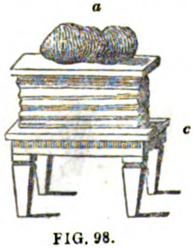


FIG. 98.

He then applied pressure at the sides, *b b*, and found that, while the superincumbent weight *a*, was raised to a certain extent, the cloths were folded and contorted, in a manner perfectly analogous to the foldings and contortions of rocks observed in nature, and portrayed in fig. 90, p. 232.

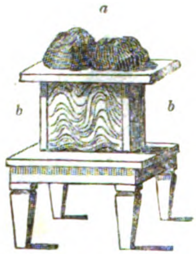


FIG. 99.

Unstratified Rocks.—The unstratified rock differs, on the other hand, from the stratified, in presenting none of those parallel surfaces, or divisions into layers, which are remarked in all sedimentary deposits; that is, in all rocks which are formed by the action of water: it usually occurs as a shapeless mass of mineral matter, as in the figure annexed.

FIG. 100

Veins of Granite and other Igneous Rocks.—We have previously mentioned, that rocks of this kind occur in the state of veins, which, especially in the instance of granite, are frequently traversed by veins still newer than themselves.

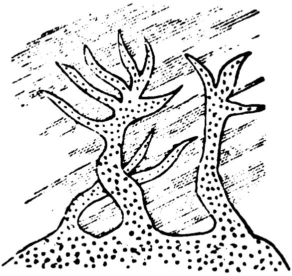


FIG. 101.

These veins often penetrate through the overlying deposits, and, soaring to the top, spread over the rocks which they have dislocated and displaced.

FIG. 102.

False Stratification.—Occasionally rocks of this kind, especially granite, at its junction with slate and other rocks, present markings of cleavage, which have

some resemblance to stratification, and might be mistaken for such. The student will, however, easily distinguish between the two, not only by the mineral composition of the rocks, but by observing that the lines resembling stratification run into one another in various directions, or are only continued for short distances.

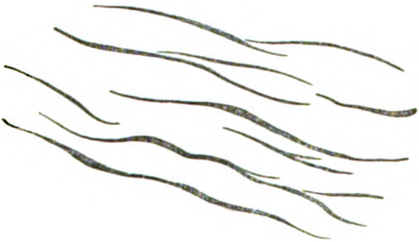


FIG. 103.

COLUMNAR ARRANGEMENT.—Several of the unstratified rocks, more especially basalt, together with porphyry and greenstone, occasionally assume a columnar form. These columns occur of three, four, five, six, and eight sides, but those with four and six form the prevailing structure. They are either continuous from top to bottom, as

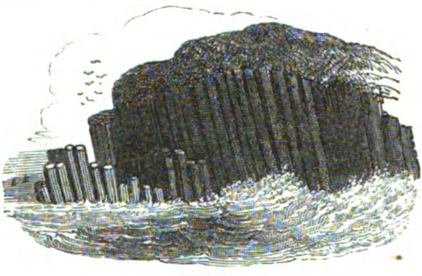


FIG. 104.

or they are jointed, and consist of a number of short prisms, placed one on the other.

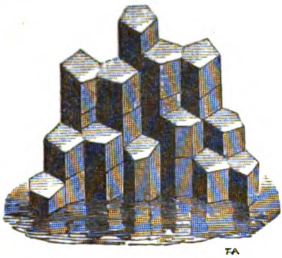


FIG. 105.

VERTICAL COLUMNS.—When basaltic columns occur in tabular masses, as at the Giant's Causeway, or Staffa, they are commonly vertical, as

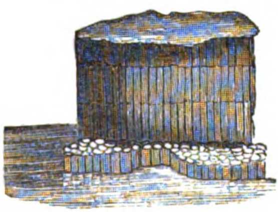


FIG. 106.

HORIZONTAL ARRANGEMENT.—When they occur in dikes, and have been erupted through overlying masses, they are usually smaller, and take a horizontal position, owing, in all probability, to the force with which they have been urged upwards, and the resistance which they have met with from the deposits which they have penetrated.

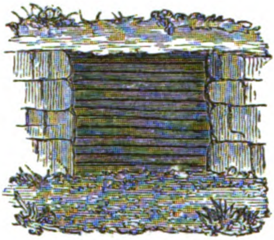


FIG. 107.

Occasionally the columnar and massive structure of basalt are exhibited in conjunction, as observed by Mr. Murchison, at Welchpool.

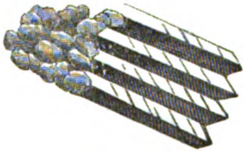


FIG. 108.

Arrangement of Deposits.—We have already spoken of the unstratified rocks, especially granite, as constituting, by the depth at which it lies, and the heights to which it is raised, both the foundation and the framework of the whole superstructure of our globe. The accompanying figure will exhibit the varied situations of the granite, both as forming the basement-rock on which all the others repose, and the mountain summits, which not only tower above the rest, but, from having been forced through the superincumbent rocks, have borne them upwards in the ascent, and have thus formed the physical geography of the entire district; the strata in the vicinity of the mountain, *a*, being raised

at an acute angle at *b*, and sinking to nearly a level position in the plains at *c*.

FIG. 109.

The form and succession of the rocks above described prevail, with some local exceptions and modifications, over the whole earth, so that its entire surface may, in fact, be considered to form a series of basins, of which the largest, deepest, and thickest lie at the bottom, and are filled up by others which, as before observed, become smaller, shallower, and thinner as they approach the top, the deposits being uplifted and raised towards the edges of these basins, and becoming level, or nearly so, towards the centre.

Dip.—The inclination of strata from a horizontal position is called their dip, the amount of the dip being the quantity of the angle which the line of inclination makes with that of the horizon, as in the accompanying figure. If the angle made by the meeting of the lines of the strata, *b b*, and the horizontal line, *a*, be equal to 45 degrees towards the east, the strata are said to dip 45 degrees in that direction.

FIG. 110.

STRIKE.—Again, the various terms of the dip, the strike, &c., of strata, will be farther understood by the following illustration. The dip, as before observed, is the line which the strata makes with the horizon: the strike is a line at right angles to the dip. In other terms, if the student only place a book on the table, with the edges of the leaves downwards, and the back of the book upwards, as in the accompanying figure,

FIG. 111.

and if he move one side of the cover a short distance, the cover so moved, *b*, will represent the line of dip, while the back of the volume, *a*, *a*, will exemplify the line of strike. If the cover of the book be extended only in a slight degree, the dip will be proportionately steep; if the cover be opened farther, so that the book lies nearly flat on the table, the dip will be proportionately less.

Having ascertained the line of dip, we can, of course, determine the direction of the strike; if the dip be towards either the north or south, the strike will be east and west; if, on the other hand, the dip be east and west, the strike will be north and south. But the converse of this position by no means holds good; for though the line of dip gives the line of strike, the line of strike does not give the line of dip, since there are

two lines of dip common to every line of strike, and strata having a line of strike running from north to south, may dip either to the east or west. In other terms, as we have moved one side of the cover of our book to the right, we can move the other to the left, *b*, while the back of the volume, *a*, *a*, still retains the same position.

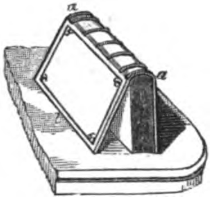


FIG. 112.

ANTICLINAL LINE.—The anticlinal line is that elevated central point from which the strata diverge in opposite directions, and to represent it we have only to extend both sides of our volume thus—

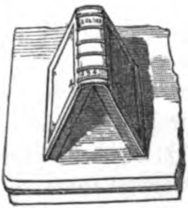


FIG. 113.

SYNCLINAL LINE.—The synclinal line is simply the reverse of the preceding, being the point at which the strata converge towards each other. To depict it we have merely to turn our book over, and open it

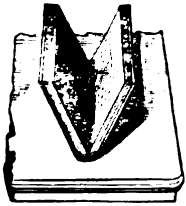


FIG. 114.

only half way, exactly at the middle, and the line between the two pages will present the synclinal line, or that point towards which the strata incline in the same direction.

The *quâ-quâ-versal* dip, is a term employed to express the appearances presented when the strata having been elevated into a boss, or dome-shaped protuberance, the summit of the dome has subsequently been carried away, and the ground-plan exhibits the edges of the strata, forming a succession of circles or ellipses round a common centre. These circles are the line of strike, and the dip, being always at right angles, is inclined, in the course of the circuit, to every point of the compass, constituting what is termed a *quâ-quâ-versal* dip, that is, turning each way.

CONFORMABLE POSITION.—Strata are said to be conformable when their general planes are parallel, whatever may be their dip, as in the following figure, where both the upper, horizontal strata, *a*, and the lower, inclined series, *b*, are conformable to each other.

FIG. 115.

UNCONFORMABLE POSITION.—When a series of upper strata rest on a lower formation, without any conformity to the position of the latter, they bespeak a more modern series, showing that the newest of the underlying group must have been deposited before the oldest of the latter. They are therefore said to occupy an unconformable position, as in the same figure 115, where the upper, horizontal beds, *a*, are unconformable to the lower, inclined deposits, *b*.

Occasionally the upper series is also raised, proving that the lower strata have been twice lifted; first, when they were themselves borne upwards; and, secondly, when the upper beds underwent a like elevation.

Various writers have cautioned the observer against certain deceptive appearances of the strata, in particular lines of coast, where beds, apparently horizontal, dip, in reality, at a very considerable angle. The following figure exhibits a headland seen from the south, in which a set of strata appear to the eye perfectly level.

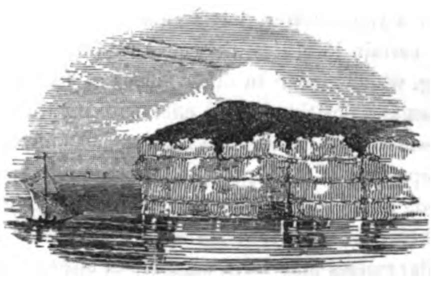


FIG. 116.

But if the headland trends off at the point *p*, to the northward, affording a view of the cliffs westward, such

view will prove that the appearance from the south is deceptive, for the lines on the western side show a considerable angle to the north, and by gradual increase of that angle become vertical at *a*.

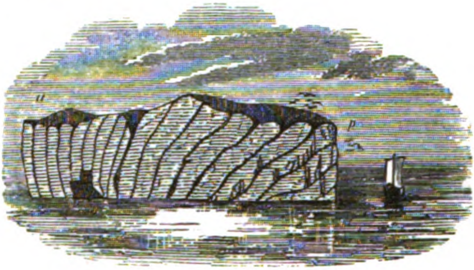


FIG. 117.

Order and Succession of Rocks.—We have before had occasion to observe, that the fossiliferous rocks follow an invariable order of succession; but that this arrangement, although never reversed, is occasionally imperfect, so that, though we never meet with *b*, going before *a*; or *c*, preceding *b*, yet we occasionally miss not only a single letter, but a succession of these, and find, in certain localities, that entire groups of strata are wanting, which occur in other places of like geological character and position. This effect, we mentioned, may have resulted either from the missing beds never having been deposited in this spot, or from their having been denuded, and carried away by the abrading power of water, before the newer strata were deposited.

Similar causes may have occasioned either the partial deposition, or partial denudation, of a single bed, and produced the thinning out of a particular stratum, as exhibited in the diagram annexed.

FIG. 118.

Age of Mountain-chains. — The conformable or unconformable position of the strata affords a safe and satisfactory guide as to many investigations of interest and importance, and from data thus furnished we learn that all the mountain-chains in the world were not of contemporaneous origin, but have been raised at different epochs, which, geologically speaking, were of modern occurrence. Thus, if on the sides of one mountain we find a series of strata, *a*, raised and covered unconformably by another group, *b*, it is obvious that the central chain must have been thrown up after the series *a*, had been deposited, but before the formation of the beds *b*.

FIG. 119.

But if on the sides of another mountain we find both the series *a*, and *b*, tilted and covered unconformably by another series, *c*, we have proofs that this mountain-chain is of more modern date than that on the sides of which the same strata, *b*, are undisturbed.

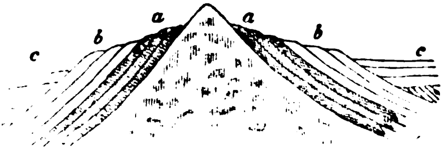


FIG. 120.

Search for Coal.—The dip of strata is frequently connected with questions of practical as well as theoretical interest. We will suppose a case—one of very frequent occurrence—where a landowner, who is aware that coal exists on an estate adjacent to his own, is desirous to ascertain if it is also to be found on his own domain, and if the attempt to discover it might be instituted with any probability of success. It has been observed with reference to such a question, that if the dip of the strata in the vicinity be towards the estate where the trial is to be made, it is probable that the coal may be found under it; but if the dip is in a contrary direction, the search ought not to be undertaken, since it would not probably lead to the desired result. The accompanying figure will explain the reason.

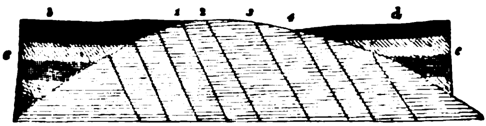


FIG. 121.

The beds 1, 2, 3, and 4, are a series of coal-strata dipping towards *d;* the unconformable strata *c*, *c*, are beds of sandstone lying over the coal. Supposing the coal-vein 4 rises to the surface at that point on the

estate of A, adjoining the estate of B, which lies towards *d*, it is then apparent that A would find only a point of the vein on his estate, and that it would be useless to search in the direction of *b*, for coal, since the dip of 4 is sufficient to prove that none exists there. But on the estate of B, though no coal came to the surface, still the dip of that which exists on the estate of A would render it highly probable that coal would be found; the possibility of the coal lying too deep for working, &c., being considerations which would depend on the angle of dip, and other circumstances of local character.

Outliers.—Strata are said to form outliers, when they constitute an isolated portion detached from the principal mass of the same bed of which they once formed a part. Thus, in the accompanying figure, the beds *a*, and *b*, form outliers of the main strata, *c*, and *d*; the missing portion having been removed by denuding causes;

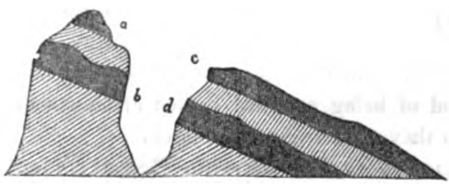


FIG. 122.

and their identity being proved by the various accordances of mineral character, order of position, and imbedded fossils.

Escarpment.—Strata are said to form an escarpment when they terminate abruptly, as at *a*, *b*, in the

above figure. Mural signifies wall-like, and a mural escarpment is applied to one of steeper and more perpendicular character.

Origin of Valleys.—We cannot be surprised that at an earlier period of the science, when the opinions of Werner very generally prevailed, and when, agreeably to his views, water was regarded as the universal agent in producing the phenomena of nature, many effects were attributed to aqueous agency which are now ascertained to have been occasioned by other causes. At this time it was usual to refer all valleys to aqueous action, and to consider them as having been produced by the rivers and streams which now flow through them. It soon, however, became evident that this cause alone was insufficient, and that in many instances they had been produced by other agencies; these conclusions being founded chiefly on the fact, that many streams, instead of running through soft and practicable strata, frequently avoid these, and find their way through rocks of harder and firmer texture. It thus became obvious, that the cause is to be sought rather in the rocks themselves, than in the streams which flow over them; and valleys are now divided into some three or four classes, instead of being confined to that of aqueous origin, to which they were originally limited.

Valleys of Dislocation.—These are caused by fissures of various dimensions, some of colossal size, which have been formed during the upheaval and separation of the strata in that region of which they form a part. They usually present steep and rapid escarpments, the strata on each side frequently bearing marks of having once been continuous. The mode by

which they have been produced will be perceived by the accompanying figure.

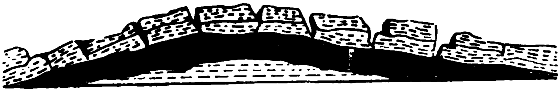


FIG. 123.

VALLEYS OF UNDULATION.—These are produced by two neighbouring elevations, which, by lifting the strata on each side without occasioning fracture or dislocation, have left a valley between, towards the middle of which their planes are inclined, and of which they form the sides. Their structure will be understood by a reference to the following illustration.

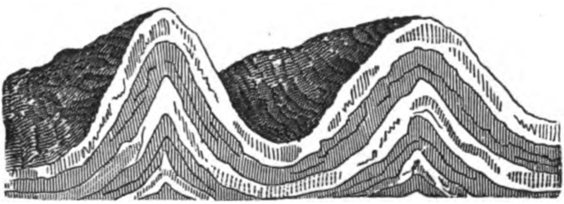


FIG. 124.

VALLEYS OF DENUDATION.—These and the succeeding class are the only kinds which have been occasioned by the action of water, and have been formed in soft and practicable strata, in the same manner as the ravines caused by storms, floods, and torrents. Valleys of this kind are of constant occurrence, and it is to such erosions that the changes so constantly taking place in the beds of rivers are to be ascribed. The term is more usually limited to those valleys where the strata are not

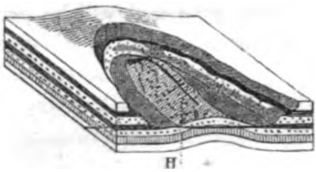


FIG. 125.

far removed from a horizontal position, and where their former continuity cannot be doubted.

VALLEYS OF ELEVATION.—These may be described as owing their origin to the circumstance, that certain beds having been originally raised in the form of a wave, have subsequently been exposed to the denuding power of water, and that a peculiar stratum harder than the rest having resisted this abrading force, has formed the kind of valley depicted in the accompanying figure, presenting a central axis whence the strata dip in opposite directions.

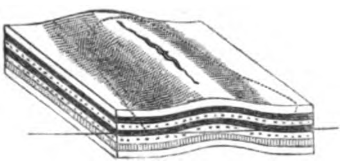


FIG. 126.

ORIGIN OF CAVERNS.—These, in like manner, have been ascribed too generally to the agency of water. It is now ascertained that these chasms beneath the earth are owing to the same causes which have produced fissures and valleys at the surface, and that they have been occasioned by the fractures and dislocations consequent on the upheaval of the strata. At the same

time it is equally clear, that the operation of water has, in many cases, tended largely to modify the nature of these caverns, by eroding the sides and the bed, and altering their form and configuration. The fracture and dislocation of rocks at the surface have often produced the phenomenon of a natural bridge, as exemplified in the accompanying figure, which depicts that of Icononzo, in South America, which is produced by the fissuring of the strata, and the fall of two masses of rock, one above the other, extending across the chasm.

FIG. 127.

FAULTS.—The fissures and dislocations which interrupt the continuity of a bed are usually termed faults. The accompanying figure represents an example of this kind, where strata which once were continuous, either by the subsidence of the strata on one side of the fault,

or their elevation on the other, have been dislocated and displaced.

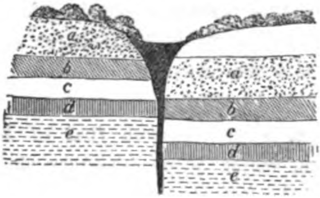


FIG. 128.

These interruptions are a source of considerable difficulty in coal-mines, where they often suddenly interrupt the miner in his course, and deprive him of the treasure of coal which he has found. They are, however, considered to offer corresponding advantages, since they counteract the tendency of the coal-seams to plunge to depths at which it would be impossible to reach them; and when filled with solid materials, they form embankments and barriers so as to keep out the water, which would otherwise flood the mine, and prevent the possibility of working it; they also act as walls and barriers, to stop the progress of flames, so that if, as frequently occurs, a fire breaks out, it is prevented from spreading beyond a limited space.

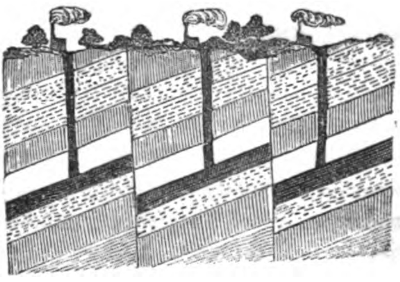


FIG. 129.

Deceptive Appearance of Faults.—These disturbances, however, frequently prove a source of loss and disappointment to speculators and inexperienced persons, who, observing different appearances of coal at the surface, conclude that they represent so many separate seams; whereas, in reality, there is but a single seam, which has been dislocated and moved to different levels, by means of faults, as

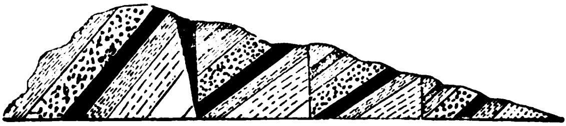


FIG. 130.

Equivalent.—Where one bed supplies the place of another, which in that situation is wanting, such stratum is called the equivalent of the missing deposit. When a bed suddenly terminates, and its place is supplied by one of different character, the latter is also called the equivalent of the former.

There are some other varieties of texture, as well as different phenomena in rocks which may be here mentioned.

Pisolites.—The pisolitic structure in certain stones is occasioned by isolated globules formed by concentric coats. They are produced by water holding foreign substances in solution, and possessing such a power of motion as to enable them continually to transport with them the grains of sand occurring in their course. Each of these grains becomes covered on all sides with successive pellicles of the substance deposited by the fluid, and it thus increases, assuming the spheroidal form, until becoming too heavy for transport it falls to the bottom of the liquid, where the whole are agglutinated

together. Occasionally each pisolite incloses in its centre a grain of foreign substance, but this is by no means a necessary condition, and the original nucleus may be a particle of the same substance in which it is enclosed. The oolitic structure, particularly of the coarser kind, strongly resembles the pisolitic, and is considered to be owing to a similar cause.

Rolled Pebbles.—Running waters have the effect of rounding those materials which they wash out of their native beds by the attrition and abrasion occasioned by such transport. A familiar illustration is furnished by the beach formed at the base of chalk cliffs, where we shall perceive that none of these flints present sharp or cutting edges, but are all worn round and smooth by the action of the waves.

Nodules.—Substances which have consolidated in the midst of semi-fluid matters often owe to the resistance thus opposed to them, a reniform, or kidney-like shape, such objects being smooth, externally, when the substance of which they are composed is little susceptible of crystallization, and furnished with crystals when it is. The former case is instanced by nodules of silex; the latter, by various substances of more crystalline character, among others, the masses of iron pyrites discovered in the same deposits.

Geodes.—Occasionally nodules of silex, and other substances, are hollow in the interior, and they are then termed *geodes*. The nodules of quartz, which present this form, are usually lined with crystals of the same substance; they occur abundantly in the county of Devon, where they bear the name of potato-stones.

Incrustations as distinguished from Petrifactions.—Waters which flow over limestone rocks have the power of dissolving a portion of the limestone, and,

on reaching the colder temperature of the atmosphere, they deposit the limestone in a solid state; a familiar example of this chemical operation being furnished by the *fur*, as it is termed, of the tea-kettle, which is formed by the water which has boiled having deposited, on cooling, a portion of the limestone which it previously held in solution. Certain springs in this country, as well as on the Continent, are famed for this property, among the former of which, those of Knaresborough and Matlock are the most celebrated. It is usual to expose objects to the action of these waters, when they become incrusted with a coating of carbonate of lime, and in this state they are frequently termed petrifactions, but improperly so, since they are merely incrusted with the stony matter, not permeated by it. For example, if we place any organic substance, as a piece of wood, or of bone, in an incrusting spring, we find that the object is merely coated with the stony matter, but internally is wood or bone still; whereas in real fossils, not only the mere external covering, but the whole of the interior structure, is converted into stone.

Authors.—The objects comprised in the term Physical Geology are so numerous and diversified, that we must again refer to the authors already named for more ample information. They may be severally consulted with advantage, for the following purposes: For the elements and combinations of rocks, read Dr. M'Culloch's Classification of Rocks, his System of Geology, and his Western Isles of Scotland; as also the Introduction of Mr. Bakewell, and the Guide and other works of Professor Phillips; for the action of water in currents, streams, rivers, lakes, and seas, and generally the dynamics, or mechanical portion of the subject, the writings of Sir H. T. Delabeche may be usefully

studied; as may those of Dr. Hutton and Professor Playfair; while the admirable publications of Mr. Lyell will be found replete with instruction in every department of the science.

EXERCISES

ON PHYSICAL GEOLOGY.

1. Commit to memory the fourfold division of rocks enumerated at the commencement of the chapter.

2. Impress on the recollection, with peculiar care, the most important characters and distinctions of the primary rocks, for the sufficient reason, that they are less clearly defined and less obvious than those of the sedimentary deposits.

3. Commit to memory the names of the successive formations, together with the distinctive features of each, under the heads already mentioned of mineralogical character, order of succession, and contained fossils. Ascertain, in like manner, the extent and depth of each respective formation, the counties in which it occurs, its relation, value, and importance, in an agricultural, economical, or commercial point of view, and commit to your note-book any general information of utility and interest.

4. Be careful to unite practice with theory, in the inquiries above suggested, and trace every system on a geological map of this country.

5. Ascertain continually the progress of geological inquiry, as regards the debatable points of drift, the glacial theory, the transport by icebergs, &c.

6. Describe the component elements of granite, gneiss, and mica-schist, with their arrangement in each.

7. What are syenite, greenstone, hornblende?

8. Name the characteristic features of the trap-rocks.

9. Describe porphyry and basalt.

10. Mention the principal volcanic products, with their chemical composition.

11. State the general characters of the igneous rocks.

12. Explain the nature of elevating and degrading causes.

13. Describe the composition of calcareous and arenaceous deposits, and the most ready mode of distinguishing them.

14. State the cause of drift, and the chief instances of its occurrence.

15. Describe the structure and origin of slaty rocks.

16. What is meant by the term alluvium, and what are its distinctions?

17. Explain the various terms, group, formation, series, system, breccia, conglomerate, dip, strike, conformable and unconformable position, outlier, denudation, anticlinal and synclinal line, escarpment, valleys of dislocation, undulation, denudation, and elevation, &c.

18. Explain the difference in appearance and character of a stratified and unstratified rock.

19. State, in detail, the phenomenon of nature best adapted to afford an idea of a geological formation.

20. Copy or otherwise impress on the recollection, the diagrams comprised in the preceding chapter.

21. Consult any works, such as those of Murchison, Conybeare, Phillips, Buckland, Mantell, Bakewell, &c., which treat of physical geology, and copy on tracing paper, their outlines and delineations.

CHAPTER VII.

FOSSIL CONCHOLOGY.

MUSEUMS: BRITISH MUSEUM, GEOLOGICAL SOCIETY, PRIVATE CABINETS, &c.

AUTHORS: LAMARCK, DESHAYES, SOWERBY, GRAY, BROWN, TURTON, &c.

FOSSIL Conchology forms a highly essential department of study for the geologist, since the shells naturally afford the most instructive information as to the ancient seas, rivers, and lakes, of which they once were the living inhabitants, and in the mineralised beds of which they now occur. The fossil shells are to be studied by means of the recent, and the investigation of these apparently subordinate, but, in reality, important and attractive objects will be found, like all inquiries into nature, to be replete with interest and instruction.

FORMATION AND GROWTH OF SHELLS.—Shells are the hard bodies which are secreted for the purpose of cover and protection by the soft, inarticulate animals which inhabit them, called the *mollusca*.* The creature, shortly after it is formed in the egg, begins to construct its shell, and when hatched, deposits on the edge of the mouth of the little shell, which

* See a valuable paper on the Growth of Shells, by J. E. Gray, Esq., of the British Museum, in the Philosophical Transactions, vol. 123, part 2, p. 771.

covered its body in the egg, a small portion of mucous secretion. This mucous deposit next dries up, and as soon as it is dry, the animal lines it with a fresh layer, composed of other mucous matter, intermixed with other calcareous particles; and when this deposit in turn becomes hardened, the animal places on its edge another thin layer of mucous secretion, and again lines it with the mixture of mucous and calcareous particles as before. This alternate deposition of mucus, and of mucus mixed with calcareous substance, proceeds as the creature enlarges, and requires more ample cover and protection, and in this manner literally "grows with its growth, and strengthens with its strength." The shell is, in fact, moulded on the body of the animal as the body itself increases in size, forming a cover, a dwelling, a coat of mail, a shed, a boat, a ship, or a palace of pearl, adapted to the exigencies, and fitted to the shape of the wearer. The inequalities or irregularities of the body itself, are also reproduced on the shell, and the elevations, depressions, striæ, tubercles, and spines, which distinguish individual subjects, may be attributed to corresponding projections, or tentacula, or other irregularities in the fleshy form of the constructing agent. Thus, as an eloquent writer* has remarked, we find that different species of shell-fish are inclosed in various kinds of testaceous coverings. Those which defend the active family of *donax* enable them to dart away, with the swiftness of an arrow, from the approach of danger; while the shells of their less active relatives, the perambulating *solens*, or razor-sheaths, are admirably adapted to assist their movements through the yielding sand. The *chitons* walk abroad in coats

* The author of the Conchologist's Companion.

of mail, closely fitted to their shapes, and surrounded with narrow belts or margins covered with scales. The shields of the *pholades* bristle with points, resembling a file, by means of which they are defended from external injury, when occupied in slowly excavating the most solid rocks; and the hospitable mansion of the peaceful *pinna* is large enough for the reception, together with himself, of his friend and guest, the hermit-crab. The conically shaped shells of the *patella*, or limpet, remind the observer of dwellers in solitary tents; the *helices*, or snails, slowly perambulate the garden-walks, in coverings which remind us of those of a broad-wheeled wagon; the *cardia*, or cockles, are provided with thick coverings which enable them to endure the rough beating of a boisterous sea; while the shells of such species as are fragile, transparent, and scarcely able to resist the slightest pressure, are found in still ponds, and muddy ditches. Some of the bivalves, as the *mytilus*, or pearl-mussel, are enclosed in diving-bells, of an oblong or compressed form, with which they emerge from the recesses of the ocean, or plunge into its depths. The *cypræœ* are conceived to quit their vestments when continual accumulations have made them burdensome to the wearer; while their brethren of the *voluta* and *buccinum* tribes not only carry about their houses with them, but are furnished with materials for repairing any accidental dilapidations in their moving walls. The *pectens*, called, from their beautiful variety of colours, the butterflies of the ocean, expand their valves to catch the breeze, and skim along the surface of the deep. Some again, as the *arca*, are shaped like boats, and safely and skilfully navigate the waters; while others may be compared to vessels of a

larger size, and are provided, as in the instance of the *nautilus*, with pumps, cordages, paddles, and other requisites for navigation. It may be added as a fact not generally known, that so beautiful are the markings of many species of the *cypræœ*, or *porcellana*, or *cowrie*, that they are conceived to have furnished the idea of the colours depicted on china, and hence this article of manufacture is termed by every nation in Europe except ourselves, *porcelain*, from the name bestowed by the Romans on this shell.

The student is referred to cases 3 and 4, of the fifth room of the North Zoological Gallery in the British Museum, in which are provisionally placed a suite of shells, intended to exhibit the more prominent points in the economy of the mollusca. Among the interesting and instructive facts thus displayed, are—the mode of growth; the changes which take place in the shell during the increase and expansion of its inhabitant; the manner in which these creatures repair any accident to their shells, or remove, by absorption, any portion which has become unnecessary or inconvenient: these cabinets farther present illustrations of the graduation of the straight, or nearly straight tubular shells, into those of spiral character, as well as specimens of monstrosities and deformed shells; with examples of the mode in which the animals cover, with a shelly coat, any extraneous body attached to the shell; and they likewise contain an instructive series of moulds and casts.*

Mode of Study.—A complete acquaintance with objects so numerous and diversified as the shells, is obviously only to be acquired by an extensive course

* See Synopsis, edit. 1843, p. 34.

of study; and a perfect knowledge of conchology requires the labour of a life. But as the fossil shells, with the exception, it may be said, of those of the tertiary deposits, are by no means so numerous or so varied in character as the recent, a moderate degree of attention bestowed on these last will enable the student, in a short time, to learn the generic and specific characters of the recent, and to distinguish the genera, and, by degrees, the species, and even varieties of fossil shells.

In the study of conchology, as in that of mineralogy, it will be expedient that the beginner should commence by procuring a suite of specimens, and the collection may, at least at the commencement, be limited to the genera, without entering on the distinctions of species. Such collections may be procured of Mr. Sowerby, or Mr. Stutchbury; and these gentlemen, as in the associate study of the minerals, are competent to furnish the most complete and valuable information on the science. The following works will be found useful:—

Sowerby's Recent and Fossil Genera.
—— Mineral Conchology.
—— Manual of Conchology.
Woodward's Synopsis of British Fossils.
Gould's Epitome of Lamarck; an American Work.
Dubois's Epitome of Lamarck.
Morris's Tabular View of British Fossils.

In studying the shells, the pupil should proceed in the same manner as was recommended in the use of the minerals; should confine his attention to a limited portion; and direct his attention to one genus, if extensive, or at most one family at a time. With the view of becoming best acquainted with these, we should advise,

in addition to other modes, that he should procure a blank book, together with two copies of the Synopsis of the British Museum; then let him cut out the description of each separate family, entering below his own observations on the various genera and species of each.

Classification of the Shells.—The animals which inhabit the shells are divided into five distinct classes, viz.; first, the *gasteropoda*, or belly-footed, so named because they walk, or rather glide on a foot, or disk, placed beneath the stomach; they have a distinct head, and a univalve spiral shell. Secondly, the *conchifera*, or shell-bearers, which have the mouth placed at the bottom of the bag-like mantle, and are covered with a bivalve shell. The three other classes are distinguished by being destitute of any foot, as they either are attached to other bodies, float about in the sea, or walk on the tentacles, or feelers, which surround their head. They consist, first, of the *brachiopoda*, or arm-footed, so called because they have a pair of spiral arms on the sides of the mouth; they have also an attached bivalve shell: next the *pteropoda*, or wing-footed, from their having a pair of wing-like fins on the sides of the head: these have a very light univalve shell: and, lastly, the *cephalopoda*, or head-footed, so called because they walk with their head downwards, on the large feelers which surround their mouth; these last are also univalves.

The shells are farther classified (considered as shells) into the three divisions suggested by their form, viz., first, the multivalves, which are composed of more pieces than two; secondly, the bivalves, of two; and, thirdly, the univalves, of one. Of these the multivalves are few

in number, and are easily distinguished. The bivalves are the most numerous of the three, and are characterized by the shape of the shell, the hinge, the ligament, and, in particular, the teeth, which are certain prominences on each valve, usually with receptacles on the opposite side to admit them, so as to interlock and secure the union of the valves. The teeth vary in form, size, number, arrangement, position, and other characters, and are straight, cone-shaped, compressed, or bent, large or small, numerous or few, placed on the hinge, or at the sides; and according to these and other characteristics, the various genera are determined.

The univalves are commonly discriminated by the shape and appearance of the shell itself, the form of the spire, the whorls, the aperture, the lips, the columella, or pillar, &c.

The univalves and bivalves are farther distinguished, as follows:—The animals inhabiting the former are the *mollusca*, strictly so termed, as the snail, &c.; while those which occupy the latter are termed *conchifera*, or shell-bearers, as the scallop, the cockle, &c. The former are of a higher degree of organization than the latter, as they possess a head and eyes, while the latter are destitute of both, and hence are also named *acephala*, having no head.

It may here be expedient to remind the student, that the only natural distinction is that of species, that of genus being merely a conventional arrangement, formed by man for the convenience of study, and that this maxim is no where more strongly exemplified than in the instance of the shells, among which we find various genera to graduate and pass almost imperceptibly into each other; as, for example, among many others, the

cyclas, which merges into *cyræna*, and the *unio*, which glides in like manner into *anodon*.

Casts of Shells.—In examining the fossil shells, the student will frequently have to decide by the general appearance of the shell alone, the hinge, or teeth being obscured or hidden by the stone, or other indurated substance with which the shell is filled. Indeed, with the exception of those of the tertiary deposits, though these are often similarly circumstanced, this is the usual condition of fossil testacea, while their characters are frequently rendered still more indistinct from the shell itself being decomposed and removed, leaving only its cast behind impressed on the substance which has occupied it. It is satisfactory to announce that, with a view to facilitate the study of these casts of nature, Professor Agassiz has ingeniously constructed a series of models, by pouring liquid plaster of Paris into recent shells, allowing it to dry and harden, and then breaking the shell to extract the contents. A suite of these objects has been purchased by the Trustees of the British Museum, and placed in the gallery adjoining the geological department mentioned above. They are calculated to be eminently useful and instructive, not only as showing the markings of the mantle, displaying the general character of the shells, and proving how completely and exactly they are moulded on the animal, but as illustrating the character and appearance of natural casts, and the moulds formed by perished shells on the substance which has filled them.

Description of Fossil Shells—It may here be suggested that the most eligible course for the young geologist to adopt, when a collection of fossils or shells, from British localities, is placed before him for arrange-

ment and description, is as follows. First, ascertain, if possible, the spot whence they were procured, then, either from memory, or by referring to the map, it will speedily be perceived to what peculiar geological formation the spot in question appertains. An inspection of the form, outline, and general characters of the shells, as we are now about to detail them, will generally furnish information as to the genus; a reference to the index of Woodward's Synopsis will guide to the page where its species are enumerated; such enumeration will usually comprise a mention of the plate in Sowerby's Mineral Conchology, or some similar work, where it is figured and described; and from the figure and accompanying description, any shell of previous occurrence may easily be identified.

We have already mentioned that vestiges of fossil shells occur either as the shell itself, the cast which it has impressed upon the substance that it has inclosed, or the mere impression which it has left on the object with which it has been in contact. It may be added, that perfect shells abound usually in the tertiary or upper secondary rocks, while the older and more deeply seated strata, owing to the pressure which they have undergone, present chiefly but casts and impressions.

Changes in Nomenclature.—It may be necessary to apprize the student that Mr. Murchison, in his splendid work on the Silurian System, has adopted certain generic names, originally proposed by the Swedish naturalist Dalman, which have been adopted by most continental geologists, but previously to Mr. Murchison's publication were unknown to us. They are subdivisions of the extensive family *terebratula*,

and Mr. J. de Carle Sowerby gives the following reasons for their adoption :—

"The generic names *leptæna*, *atrypa*, and *orthis* have been adopted from Dalman's Memoir in the Stockholm Transactions, in deference to the opinions of that author. The first derived from λεπτος, slender, stands in the place of *producta* or *productus*, a name to which grammarians have objected.

"The second genus, *atrypa*, from α privative, and τρυπα, meaning without a hole or foramen, is divided from *spirifer*, and includes those species which have a short hinge-line, without a large area, and are either destitute of a foramen, or possess only a small triangular one. They are rounded shells, and are not furrowed like the typical species of *spirifer*; the internal spiral arms are preserved in some species. *Atrypa affinis*, and similar striated shells, would form another natural group, in which the internal structure, as well as the general form, is different; for the spiral appendages, if ever they possessed any, do not appear to remain, and there are two short crenated teeth in the hinge; the species of this division have usually been described as *terebratulæ* by British authors; but they have acute, not perforated beaks.

"The genus *orthis*, (from ορθος, straight,) is another division of *spirifer*, no species of which has heretofore been described in England; it is distinguished from *spirifer* by the long narrow hinge, and circular flat form of the striated shells.

"Our genus *pentamerus*, is called *delthyris* by the Swedes, but we see no reason for altering the name."

The author would suggest his conviction, that several of the names now bestowed on fossil shells require a like

alteration and revision. The shells termed *amphidesma* seem scarcely such as can with propriety be referred to the recent genus of that name; and it may be doubted with reference to the genus *plagiostoma*, whether such shells as *p. giganteum* of the lias, and *p. spinosum* of the chalk, can be attributed to the same genus.

It is to be expected that as more attention is paid to the general characters of shells, and in particular to the nature of their animal inhabitants, various changes will be introduced. Thus Professor Forbes, the able and zealous curator of the Geological Society, has determined that the *orthoreca*, which has hitherto been ranked among the cephalopodous order, belongs in reality to the gasteropodous division. In confirmation of this view we may state, that whereas it had always been found extremely difficult, in fact impossible, to trace the siphuncular tube, it appears that the shell never possessed this structure at all. The shell is now named *criseis*.

Attention was drawn some time since to some new forms of *ammonites* discovered in the Kimmeridge clay of the oolite, which will be figured and described in the future chapter which we shall devote to that system of deposits, the chief feature of which consisted in a long, spatulate projection issuing from the mouth of the shell, uuknown in any other species. This process is now considered to be no more than a mere specific distinction, and to have been of no vital importance as regards the economy or habits of the animal inhabitant.

Plate of the Shells.—We have now to call attention to the following series of figures, depicting the various parts, both of multivalve, bivalve, and univalve shells.

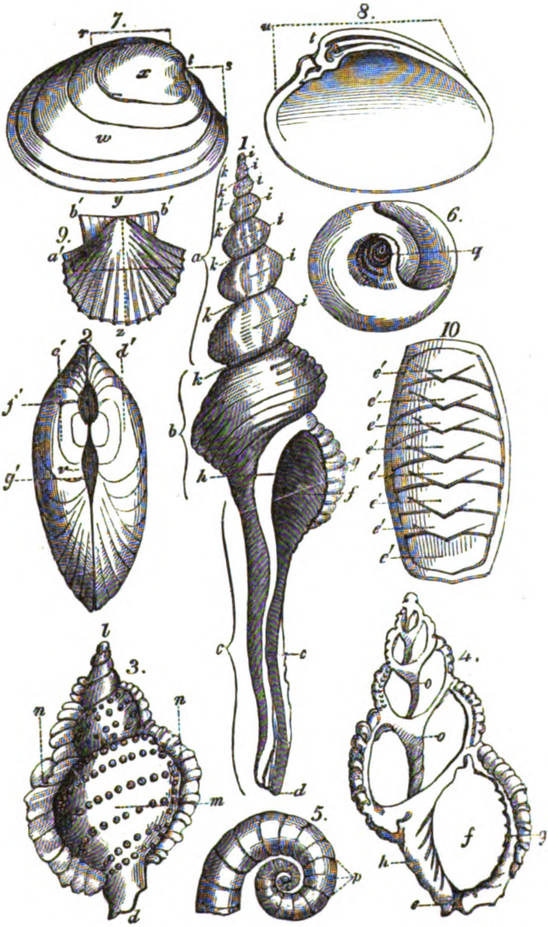


FIG. 131.

We subjoin an explanation of the accompanying plate in a tabular form, with a description of the separate parts of the shells there depicted, commencing with the univalves.

a. Spire
b. Body-whorl
c. Beak
d. Base
e. Canal
f. Aperture
g. Labrum, or outer lip
h. Labium, or columellar lip
i. Whorls
k. Suture
l. Apex, or vertex
m. Back
n. Varices
o. Columella
p. Septa, or dissepiments
q. Umbilicus
r. Area, or anterior slope
s. Areola, or posterior slope
t. Beaks
u. Hinge
v. Ligament
w. Disk
x. Umbo, or nates
y. Base
z. Length
a' Breadth
b' Auricles
c' Left valve
d' Right valve
e' Valves
f' Lunule, or anal depression
g' Corselet, or escutcheon.

The spire, fig. 1, *a*, consists of all the whorls of the shell, except the last, which is called the body of the shell. The spire forms a very important feature in the univalves, and on its being raised, flattened, concealed, or reversed, depend many of the generic and specific distinctions of the shells.

The body-whorl, fig. 1, *b*, is, as before stated, the lowest; the aperture is situated in it, and it is in general larger than the remaining whorls.

The beak, or *rostrum*, fig. 1, *c*, is that lengthened process in which the canal is situate; it commences a

little higher up, on the outside, than the insertion of the canal on the inside, which is always distinctly marked by the line of the aperture.

The base, figs. 1 and 3, *d*, is the opposite extremity of the *apex*, or tip of the spire. In shells with a beak, it is the extreme point of such beak; in those without a beak, it is understood to be the lowest part opposite the *apex*.

The canal, or gutter, figs. 1 and 4, *e*, is the elongation of the aperture, in both lips of those shells which have a beak, in which it forms a concave channel, or gutter, running from its commencement in the aperture, to its termination at the extremity or base.

The aperture, or mouth, figs. 1 and 4, *f*, is the opening of the lower whorl, at which the animal protrudes itself, constituting one of the most important generic distinctions of univalve shells, and differing extremely as to shape, being circular, crescent-shaped, angular, linear, &c. &c., Some apertures have a canal at their base, while others have none. In some genera it extends the whole length of the shell, as in the *cypræœ*, and some of the cones with depressed spires.

The *labrum*, or outer lip, figs. 1 and 4, *g*, is the expansion, or continuation of the body of the shell, on the left margin of the aperture, and is lined with the same pearly process as the aperture itself.

The *labium*, or inner, or columellar, or pillar-lip, figs. 1 and 4, *h*, is a continuation of the glossy process of the aperture, expanded on the columella.

The whorls, fig. 1, *i*, are the wreaths or volutions of the shell, tapering gradually upwards, from the lower and largest, to the uppermost and smallest, at the point of the spire.

The suture of the whorls, fig. 1, *k*, is a fine spiral line, which separates the wreaths, or whorls, from each other. It is occasionally crenulated, undulated, sulcated, and sometimes raised or projecting.

The *apex*, or *vertex*, fig. 3, *l*, is the highest point of the spire.

The back, fig. 3, *m*, is the side directly opposite to that in which the aperture is placed.

The *varices*, fig. 3, *n*, are ribs which cross the whorls of shells, in some species of *buccinum*, *murex*, and *triton*. They are formed by the periodical growth of the shells, these being the margin of the outer lip, to which the animal has attached its successive enlargements.

The *columella*, or pillar, fig. 4, *o*, is that process which runs through the centre of the shell in the inside, usually from the base to the apex, appearing to be the support of the spire, and, in fact, to form that part of the shell. It constitutes an important feature in univalve shells, and on the mode in which it is striated, grooved, folded, or otherwise marked, depend the generic and specific distinctions of many shells. It also forms the axis of revolution around which the whorls are turned. In consequence of the heart and great blood-vessels being usually placed on the left of the shell, the turns are commonly made from right to left; on the contrary, where the heart and blood-vessels are placed on the right side, the whorls are reversed, and proceed from left to right. In the first, or normal instance, the shell is termed *dextral*; in the latter, or irregular case, it is called *sinistral*, *reversed*, *heterocrital*, or *heterostrophe*.

The *septa*, or dissepiments, or chambers, fig. 5, *p*,

are the cavities, divided by partitions, as in the nautilus, &c.

The *umbilicus*, fig. 6, *q*, is in general a circular perforation in the base of the lower whorl, or body of many univalve shells. Such is the case in the genus *trochus*, in some species of which it penetrates from the base to the apex, being widest at the base, and gradually tapering towards the top. Those shells which have no *umbilicus* are termed *imperforate*.

We will now direct our attention to the bivalves, and we find that fig. 2 represents a bivalve shell placed in its right position. The right position is that in which the *lunule*, or smaller depression, is uppermost. Great care must be taken to ascertain this proper position, as considerable confusion has taken place in works on conchology, in consequence of this point not having been correctly determined.

The *area*, or full space, or anterior slope, fig. 7, *r*, is that part of the shell in which the ligament is placed.

The *areola*, or lesser area, or posterior slope, fig. 7, *s*, is the space opposite to that in which the ligament is placed.

The beaks, figs. 7 and 8, *t*, are the extreme points of the summits of bivalves, which very commonly turn downwards, as in *venus*, or spirally downwards, as in *isocardia*. Owing to this circumstance, they very seldom form the highest point of the shell.

The hinge, fig. 8, *u*, is the point at which bivalve shells are united, either by the teeth of one valve inserting themselves between those of the opposite valve, or by the teeth of one fitting into the cavities or sockets of the other.

It is on the peculiar construction of the hinge, in

conjunction with the general contour of the shell, that the generic character of bivalves is principally founded.

The ligament, fig. 9, *v*, is that flexible, cartilaginous substance by which the valves are united, and the hinges kept in their place. It is always situated under the beaks of the shell.

The disk, fig. 7, *w*, is the convex centre of a valve, or the most prominent part of the valve.

The *umbo*, or *nates*, fig. 7, *x*, is the part situated immediately under the beak.

The base, fig. 7, *y*, is the part immediately opposite the beak.

The length, fig. 9, *z*, is measured from the beak to the base.

The breadth, fig. 9, *a′*, is calculated from the extreme edge of the anterior and posterior slopes, being in a contrary direction to the length.

The auricles, or ears, fig. 9, *b′*, *b′*, are the processes on each side the beak in the genus *pecten;* some species have one ear very large, and the other extremely small, while some are scarcely discernible on one side.

The left valve, fig. 2, *c′*, is that which, when the shell is placed, as in the plate, with the lunule uppermost, is on the left hand of the spectator.

The right valve, fig. 2, *d′*, is the reverse of the above, and is on the spectator's right.

The valves of a multivalve shell are depicted in fig. 10, *e′*.

The *lunule*, fig. 2, *f′*, is the anal, or smaller depression, posterior to the beaks.

The *corselet*, or escutcheon, fig. 2, *g′*, is the larger depression anterior to the beaks.

Explanation of Terms.—There are a few other

terms which may require explanation; thus the muscular impression is the mark made by the adhesion of the animal to the shell. It is *single* or *double*, accordingly as the animal possesses one or two muscles; and varies in shape, being *circular*, *ovate*, *lunate*, *elongated*, &c. &c. As a specific distinction, it is of great use, being, with very few exceptions, alike in the same species. The animals, as they respectively possess one or two muscles, are termed *unimusculosa* and *bimusculosa*. As the *unimusculosa* are all fresh-water shells, and the *bimusculosa* all marine, this fact alone is sufficient to determine the character of the shells, and consequently, when they occur in a fossil strata, the origin, whether fresh-water or marine, of the strata in which they are found.

The margin is the circumference of the shell, or the extreme edge all round; it is occasionally *crenulated*, or notched, as in most species of the *cardium*, or cockle, and some of *donax*.

Striæ are fine thread-like lines, generally on the exterior surface of shells, and are sometimes both longitudinal and transverse.

If both valves are of the same size, the shell is said to be *equivalve*.

If one valve is larger than the other, it is said to be *inequivalve*.

If both sides are equal, it is termed *equilateral;* if one is larger than the other, it is called *inequilateral;* while the prefix *sub*, means nearly, thus, *subequivalve*, signifies nearly equivalve, &c.

THE TEETH.—The teeth constitute a highly important characteristic, since they serve chiefly to deter-

mine the specific distinctions. They are *cardinal*, that is, placed in the centre; or *lateral*, that is, diverging from the *umbo;* they also vary extensively in shape and direction, being *incurved*, or bent round, *recurved*, or turned back, large or small, numerous, few, rounded, flattened, &c. &c.

The Mantle.—The mantle is a *sac* full of pores and glands, which envelopes the mollusca; it is moistened with a slimy exudation: occasionally it quite encloses the animal, leaving but one opening like a purse; sometimes it has expansions at the sides like fins, and, in some instances, it spreads over the shell.

Operculum.—This is a lid, by means of which many of the molluscous animals close the aperture of their shells. In some cases it is testaceous; in others horny, or cartilaginous. It is affixed to the animal, and in multivalves consists of four pieces. It is calculated for the protection of the creature when it retires within its dwelling, of which it may be termed the door, and is adapted to the shape of the aperture, which it covers completely. The common periwinkle affords a familiar example.

Epidermis.—This is the thick outer skin, or cuticle, with which the exterior surface of many of the univalve and bivalve shells are covered. It is membranaceous, and resembles the *periosteum*, or skin which covers the bones of animals. It seems to be formed entirely by the animal, and is constantly found in some species, and never in others; those with a ragged surface almost always possess it. In some it is laminated, velvety, fibrous, or rough; in others, it is thin and pellucid, allowing the colours of the shell to show through it.

It often falls off of its own accord, and without any injury to the surface of the shell. The beauty of many shells is hidden by this outer coat.

With a view to exemplify some of the characteristics which we have detailed, we will here quote the description of one of the most familiar genera, both of univalve and bivalve shells.

Turbo.—Shell conoid, (that is, shaped like a cone,) or subturreted, (rather like a turret or a tower,) outline never compressed; aperture entire, (without a canal or gutter;) rounded, not modified by the penultimate whorl, (the whorl before the last,) margins separate above. Columella arcuated, (pillar curved like a bow,) flattened, not truncated (not cut off square at the base.) Operculum, (having a lid at the aperture.)

The above is a description of that genus of which the periwinkle is a species. We now proceed to describe a bivalve.

Cardium.—Shell equivalve, (the valves of the same size,) subcordiform, (shaped somewhat like a heart;) beaks protuberant; valves dentated (toothed) or plaited on the internal edge. Hinge, with four teeth on each valve; the two cardinal or central teeth approximate, (near to each other,) and oblique, (not straight,) the two lateral or outer teeth articulating (interlocking) with their opponents; two lateral (side) teeth, remote and entering into cavities which admit them on the opposite side.

Such is a description of the genus *cardium*, or cockle.

We append the names of some of the most familiar genera of shells, with translations.

Acasta, one of the Oceanides.
Acera, *Gr.* without a horn.
Achatina.
Alasmidonta, *Gr.* without a lateral tooth.
Ammonites, *Ammon*, a name of Jupiter.
Ammonoceratites, *Gr.* the horn of Ammon.
Amphidesma, *Gr.* ligament external and internal,
Amphitrite, one of the Nereids.
Ampullaria, *Lat. ampulla*, a wide-mouthed bottle.
Anastoma, *Gr.* mouth looking upwards.
Anatifera, *Gr.* producing ducks.
Anatina, *anas*, *Gr.* a duck.
Ancillaria, from *Lat. ancilla*, a damsel.
Ancylus, *Lat. ancile*, a sacred shield.
Anodonta, *Gr.* having no teeth.
Anomia, *Gr.* without law, anomalous.
Arca, *Lat.* a chest, or ark.
Arenicola, *Lat.* inhabiting the sand.
Argonauta, *Gr.* sailors in the ship Argo.
Aspergillum, *Lat.* a watering pot.
Auricula, *Lat.* a little ear.
Avicula, *Lat.* a little bird.
Baculites, *Lat. baculum*, a staff.
Balanus, *Lat.* an acorn.
Belemnites, *Gr.* a dart.
Birostrites, *Lat.* double-beaked.
Buccinum, *Lat.* a trumpet.
Bulimus, *Lat.* insatiable thirst.
Bulla, *Lat.* a bubble.
Bullæa, *Lat.* like bulla.
Calceola, *Lat.* a little shoe.
Calyptræa, *Gr.* a cap for the head.
Cancellaria, *Lat. cancelli*, like pales of a fence.
Capsa, *Lat.* a coffer, or box
Cardita, allied to cardium.
Cardium, *Lat.* a heart.
Carinaria, *Lat. carina*, the keel of a vessel.
Carocolla, *Gr. caracalla*, a kind of hood.
Cassidaria, allied to cassis.
Cassis, *Lat.* a helmet.
Castalia, name of a daughter of Achelous.
Cerithium, *cerites*, a wax-coloured gem.
Chama, *Gr.* pronounced kama, to gape.
Chiton, *Gr.* pronounced kiton, a coat of mail.
Chitonellus, *Lat.* little chiton.
Clausilia, *Lat. claudo*, to shut.
Clavigella, *Lat. clava*, a club
Cleodora, name of a nymph.
Clio, name of a nymph, and a muse.

Clymene, one of the Nereids
Columbella, *Lat. columba*, a little dove.
Concholepas, *Lat.* conch like a lepas.
Conolites, *Lat.* from *conus*, a cone.
Conus, *Lat.* a cone.
Corbis, *Lat.* a basket.
Corbula, *Lat.* a little basket.
Coronula, *Lat. corona*, a crown.
Crania, *Lat.* a scull.
Crassatella, *Lat. crassus*, somewhat thick.
Crenatula, *Lat.* a little notch.
Crepidula, *Lat. crepida*, a little shoe.
Creusia.
Cyclas, *Gr.* orbicular.
Cristellaria, from *crista*, *Lat.* crest, or tuft.
Cucullæa, *Lat. cucullus*, a hood.
Cyclostoma, *Gr.* circular mouth.
Cymbulia, *Lat. cymbula*, a little boat.
Cypræa, *Lat. Cypris*, a name of Venus.
Cypricardia, allied to cyprina and cardium.
Cyprina, from Cyprus, consecrated to Venus.
Cyrene, daughter to the river Peneus.
Cytherea, a name of Venus.
Delphinula, *Lat. delphinus*, a dolphin.
Dentalium, *Lat. dens*, a tooth.
Diceras, *Gr.* with two horns.
Discina.
Discorbites, from *Lat. discus*, a disk, and *orbis*, an orb.
Dolabella, *Lat.* a little axe, or hatchet.
Dolium, *Lat.* a tun.
Donax, *Lat*, a wedge.
Eburna, *Lat. ebur*, ivory.
Emarginula, *Lat. emarginatus*, a notched margin.
Erycina, a surname of Venus.
Etheria, one of the sea-nymphs.
Fasciolaria, *fasciola*, *Lat.* a little band.
Fissurella, *Lat.* a little fissure.
Fistulana, *fistula*, *Lat.* a pipe.
Fusus, *Lat.* a spindle.
Galathea, name of a sea-nymph.
Galeolaria, *Lat. galea*, a helmet.
Gastrochæna, *Gr.* body gaping.
Glycimeris, *Gr.* name of a shell.
Gryphæa, *Gr.* with a hooked nose.
Haliotis, *Gr.* the sea-ear.
Harpa, *Lat.* a harp.
Helicina, *Lat.* like helix.

Helix, *Lat.* a spiral line.
Hiatella, *Lat.* *hiatus*, the little gaper.
Hippopus, *Gr.* horse's foot.
Hippurites, from *hippuris*, *Lat.* the herb mare's tail.
Hyalæa, *Gr.* a glass.
Hyria, a honey-comb.
Iridina, *Lat.* *iris*, a rainbow.
Isocardia, *Gr.* symmetrical heart.
Janthina, *ianthum*, a violet.
Laplysia, *Gr.* a sponge that cannot be cleaned.
Lenticulites, *Lat.* *lenticula*, a little lentil.
Lima, *Lat.* a file.
Limax, a snail, or slug.
Limacina, from *Lat.* *limax*.
Lingula, *Lat.* a little tongue.
Lituolites, from *Lat.* *lituus*, crooked trumpet.
Loligo, *Lat.* for a cuttle fish.
Loligopsis, *Gr.* like loligo.
Lucina, name of a goddess.
Lutraria, *Lat.* *lutra*, an otter, from frequenting mud.
Lymnea.
Mactra, *Lat.* a kneading-trough.
Magilus.
Malleus, *Lat.* a hammer.
Marginella, *Lat.* *margo*, a margin, alluding to the outer lip.
Melania, *Gr.* black.
Melanopsis, *Gr.* like melania.
Meleagrina, *Gr.* a guinea-fowl.
Melonites, from *Lat.* melo, a melon.
Miliolites, from *Lat.* *milium*, millet.
Mitra, *Lat.* a mitre.
Modiola, *Lat.* a little measure, or bucket.
Monoceros, *Gr.* one-horned.
Monodonta, *Gr.* one tooth.
Murex, *Lat.* a shell producing purple.
Mya, *Gr.* a mussel.
Mytilus, *Lat.* for a kind of mussel.
Natica, adapted for sailing.
Nautilus, *Lat.* *nauta*, a sailor.
Navicella, *Lat.* *navicula*, a little boat.
Nerita, *Gr.* hollow.
Neritina, *Lat.* like nerita.
Nodosaria, from *nodus*, *Lat.* a knot.
Nucula, *Lat.* a small nut.
Nummulites, *Lat.* *nummulus*, a small coin.
Octopus, *Gr.* a foot.
Oliva, *Lat.* an olive.
Onchidium.
Orbicula, *Lat.* a little ball.
Orbiculina, *Lat.* *orbiculus*, a little orb.
Orbulites, *Lat.* *orbis*, an orb.
Orthocera, *Gr.* straight horn.

Ostrea, *Lat.* an oyster.
Otion, *Gr.* a little ear.
Ovula, from *Lat. ovum*, an egg.
Paludina, *Lat. palus*, a marsh.
Pandora, alluding to Pandora's box.
Panopæa, *Gr.* all aperture.
Parmacella, *Lat. parma*, a little shield.
Parmophorus, *Gr.* shield-bearing.
Patella, *Lat.* a bason, the knee-pan.
Pecten, *Lat.* a comb.
Pectinaria, from *pecten*, a comb.
Pectunculus, a shell-fish.
Pedum, *Lat.* a shepherd's crook.
Perna, *Gr.* a gammon of bacon, a pig's foot.
Petricola, *Lat.* inhabiting rocks.
Phasianella, *Lat.* a little pheasant.
Pholas, *Gr.* a burrow, to pierce.
Phyllidia.
Phylliroe.
Physa.
Pileopsis, *Gr.* like a bonnet.
Pinna, *Lat.* a plume, or feather.
Pirena, *Gr.* the point of a sword.
Placentula, *Lat.* a little cake.
Placuna, *Gr.* a boad table.
Plagiostoma, *Gr.* an oblique mouth, (the *g.* pronounced hard.)
Planaxis, *Lat.* flattened axis?
Planorbis, *Lat.* flat orb.
Pleurobranchus, *Gr.* branchiæ at the side.
Pleurotoma, *Gr.* having the edge cleft.
Plicatula, *Lat. plica*, a little fold, or wrinkle.
Pneumodermon, *Gr.* skin like lungs.
Podopsis, *Gr.* like a foot.
Pollicipes, *Lat. pollex*, the thumb, and *pes*, the foot, great toe.
Polygyra, *Gr.* many whorls.
Polystomella, *Gr.* many-mouthed.
Psammobia, living in sand.
Pterocera, *Gr.* horned wing.
Pterotrachea, *Gr.* winged trachea.
Pupa, *Lat.* a puppet.
Purpura, *Lat.* a shell producing purple.
Pyramidella, a pyramid.
Pyrgoma, *Gr.* a tower.
Pyrula, *Lat.* a little pear.
Radiolites, *Lat. radius*, a ray.
Ranella, *Lat.* a little frog.
Renulites, *Lat.* fron *ren*, a kidney.
Ricinula, *Lat.* like the castor-oil seed.
Rostellaria, *Lat.* a little beak.

Rotalites, *Lat. rota*, a wheel.
Rotella, a very small wheel.
Sabellaria, *Lat. sabellum*, coarse sand.
Sanguinolaria, *Lat. sanguis*, blood.
Saxicava, *Lat. saxum*, a rock, and *cavo*, to hollow.
Scalaria, a flight of stairs.
Sepia, from *Lat. sepio*, to cover or conceal.
Septaria, *Lat. septum*, a division.
Serpula, *Lat.* a serpent.
Siderolites, *Lat.* from *sidus*, a star.
Sigaretus.
Siliquaria, *Lat. siliqua*, a bean-pod.
Solarium, *Lat.* a sun-dial.
Solen, *Gr.* a pipe or tube.
Solenomya, allied to solen and mya.
Sphærulites, *Lat. sphærula*, a little globe.
Spirolinites, from *Lat. spirula.*
Spirorbis, a spiral orb.
Spirula, a little spire.
Spondylus, *Gr.* head of a prickly artichoke.
Stomatella, *Gr.* a little mouth,
Stomatia, *Gr.* like a mouth.
Strombus, *Lat.* a sort of shell-fish.
Struthiolaria, *Gr.* an ostrich.
Succinea, *Lat.* amber-coloured.
Symphinota, *Gr.* united at the back.
Tellenides, *Gr.* like tellina.
Tellina, *Gr.* the name of a swift fish.
Terebellum, *Lat.* a little auger.
Terebella, *Lat.* a little auger.
Terebratula, *Lat. terebratus*, pierced.
Teredina, resembling teredo.
Teredo, *Gr.* a worm that bores wood.
Testacella, *Lat.* a little shell.
Tornatella, *Lat. torno*, to turn in a lathe.
Tridacna, *Gr.* three bites.
Trigonia, *Gr.* three corners.
Triton, *Gr.* a sea deity.
Trochus, *Lat.* a child's top.
Tubicinella, *Lat.* a little trumpet.
Turbinella, *Lat.* like a wreath.
Turbo, *Lat.* a wreath.
Turrilites, *Lat. turris*, a tower.
Turritella, a little tower.
Umbrella, *Lat.* a little shade.
Ungulina, *Lat. ungula*, a hoof.
Unio, *Lat.* a pearl.
Valvata, *Lat. valva*, a folding door,
Vermetus, *Lat. vermis*, a worm.

Venericardia, allied to venus and cardium.
Vermilia, *Lat. vermis*, a worm.
Vitrina, *Lat. vitrum*, glass.
Volvaria, *Lat. volvo*, to roll.
Voluta, *Lat.* a volute, or scroll.
Vorticialis, *Lat. vortex*, a whirlpool.
Vulsella, *Lat.* tweezers.

EXERCISES

ON CONCHOLOGY.

1. Describe the structure and formation of shells, their growth, and the principle on which the form of the shell is regulated.

2. Mention the forms and habits of the various genera detailed in p. 262.

3. Name the classification of shells.

4. Explain the terms *gasteropoda*, *conchifero*, *brachiopoda*, *petropoda*, *cephalopoda*; and *mollusca*, and *acephala*.

5. Describe a univalve, bivalve, and multivalve shell.

6. Copy and commit to memory the names of the various parts of a univalve shell, describe each part, and the functions it is destined to fulfil.

7. Copy a list of the genera of univalve shells.

8. Describe in like manner the bivalves, their various parts, with the derivation of their names, and the offices for which they are designed.

9. Transcribe a list of the genera of bivalves.

10. Describe the multivalves in a similar manner.

11. Copy on tracing paper the outline of the plate

271, with the view to impress still more strongly on the memory the various parts of shells and the purposes for which they are respectively intended.

12. State the characters by which the genera of univalve and bivalve shells are determined.

13. Explain the distinction of genus and species.

14. Describe a familiar genus of a univalve shell, as *helix*, a snail; or *buccinum*, a whelk; and of a bivalve, as *mytilus*, a mussel; or *pecten*, a scallop; and compare your own descriptions with those of authors.

15. Consult with care the list of the names of the shells, and impress on the memory the derivation of each.

16. Explain the terms comprised in the explanation of the plate, from the spire (*a*) to the corselet (*g'*).

17. What is meant by the term muscular impression?

18. Explain the terms *striæ*, equivalve, inequivalve, subequivalve, equilateral, inequilateral, subequilateral, &c.

19. State the distinctive characters of the teeth.

20. What is the mantle, the *operculum*, the *epidermis?*

21. What is the most eligible mode of determining and describing fossil shells?

22. Copy and commit to memory the alterations in nomenclature, proposed by Mr. Sowerby, as regards the genera *leptæna*, *atrypa*, and *orthis*.

23. Select farther exercises from the foregoing chapter, and transpose its statements into questions to be answered forthwith, as for example, taking the parts of an univalve shell. What is the spire, the body-whorl, the beak, &c.? and the same with the bivalves. What are the valves, the beaks, the hinge, the base, &c.?

How is the length of the bivalve measured? How the breadth, &c. &c.

24. Be careful, as in every other instance, to unite practice with theory, and to study the various characters with a specimen in hand, for reference and exemplification.

CHAPTER VIII.

FOSSIL BOTANY.

AUTHORS:—LINDLEY, HUTTON, ARTIS, WITHAM, BUCKLAND, STERNBERG, PRESL, GOPPERT, COTTA, SCHLOTHEIM, BRONGNIART.

MUSEUMS:—BRITISH MUSEUM, GEOLOGICAL SOCIETY, NEWCASTLE, DUDLEY, MANCHESTER, LEEDS, SCARBOROUGH, WHITBY, GLASGOW COLLECTIONS, &c.

THE science of Fossil Botany, like all the studies of nature, is of modern origin. M. Adolphe Brongniart observes, that scarcely any mention of fossil vegetables occurs in ancient writers, and that the few observations of Theophrastus and Pliny are too vague and obscure to be of any utility or value. The silence of Greek and Roman authors ought not, he adds, to surprise us; coal, which constitutes the great depository of fossil plants, being wanting, or undiscovered in the regions chiefly inhabited by these nations; while in Germany, France, and England, where coal is chiefly found, the Romans were intent on establishing or maintaining their domination, rather than on studying the natural resources of those districts; the extensive woods which then covered so large a portion of the surface, affording a sufficient supply of fuel, without compelling a recourse to those mineral stores, afforded by the entombed forests of the primeval earth.

Coal, however, is actually mentioned by several of the ancient writers—by Theophrastus, Sicculus Flaccus,

and St. Augustine. It is also conceived to have been known to the Roman occupants of our island, cinders and pieces of coal having been found in Roman roads and walls, and Roman coins discovered in beds of cinders. It is farther supposed to have been known to the British aborigines, hammer-heads, wedges, and axes of flint, evidently British, having been found in beds of coal; while the very name of the substance is known to be not Saxon, but British. Indeed, we cannot but conclude, that a people who are known to have wrought veins of tin, lead, and copper, could not have continued ignorant of a substance, which often lies so much nearer the surface, and fragments of which are constantly washed out of its native beds, and borne into the plains by rivulets and streams. There is historical evidence of its having been known and employed in the ninth century, during the occupation of the Saxons; it is also mentioned shortly after the Norman Conquest. Æneas Sylvius, who visited this island about the middle of the fifteenth century, and afterwards became Pope Pius II., in a well-known passage, mentions, with evident surprise, that he saw in Scotland poor people in rags begging at the churches, and receiving for alms pieces of stone, with which they went away contented. " This species of stone," he observes, " whether with sulphur, or whatever inflammable substance it may be impregnated, they burn in place of wood, of which their country is destitute."

The study of fossil botany is considered as having commenced with the general working of coal, and though the same erroneous ideas were at first attributed to vegetable, as prevailed with reference to animal fossils; yet

the clearness and distinctness of their forms soon showed that they were actual plants; while the evidence of drift which they exhibited, occasioned them to be ascribed to the action of the deluge. It was not, however, till about the commencement of the past century that the researches and the publications of La Hire, and in particular of Scheuchzer, on the continent; and of Lloyd and Lister, in our own country, drew the attention of the scientific world to this remarkable department of natural science. At a later date, the writings of Leibnitz, Wolkmann, Mylius, Maraldi, and Jussieu, not only proved the general distribution of these fossils over a great part of Europe, but the Memoir of Jussieu, published in the Transactions of the Academy of Sciences, in 1708, is eulogized by M. Brongniart, as a work truly remarkable for its epoch; since it possesses the distinguished merit of establishing the dissimilarity which exists between the plants of the coal, and the existing vegetation of those portions of Europe in which they are now found, and their analogy with species peculiar to warmer regions at the present day.

As, at an earlier period, observers had been sceptical as to the vegetable origin of these fossils, later inquirers, as Scheuchzer, Mylius, Wolckmann, and others, flew to the opposite extreme, and not content with acknowledging them as vegetables, recognised in their imperfect and dubious impressions the characters of existing plants, and pointed out ears of corn and maize, flowers of the tulip and the aster, and the fruit of the pine-apple!

Errors, however, correct themselves, and the true characters and relations of plants were studied and

determined by the assiduous labours of several ardent and gifted inquirers, from Schlotheim, and Faujas de St. Fond, on the continent; Parkinson and Artis, in this country; and Steinhauer, in America, up to the distinguished continental botanists, Sternberg, Presl, Cotta, Nœggerath, Agardh, Nillson, Nau, Martius and Brongniart; and their worthy fellow-labourers in this country, Buckland, Witham, Bowman, and Lindley and Hutton, at the present day.

The most useful works on the subject are the *Prodrome* and the *Histoire des Végétaux Fossiles*, both by Adolphe Brongniart; the *Versuch einer Geognostisch-Botanischen Darstellung der Flora der Vorwelt*, usually termed for brevity, *Flora der Vorwelt*, or Flora of the Ancient Earth, by Count Gaspar Sternberg, continued after the blindness and decease of this venerable and ardent cultivator of science, by Presl. As the foreign publications here enumerated are large and expensive, and as they chiefly relate to forms of plants derived from foreign localities, and not occurring so frequently in this country, the reader is recommended to commence with the excellent and more portable English work, entitled the Fossil Flora, by Dr. Lindley and Mr. Hutton.

Classification of Vegetables.—The student of fossil botany will find it expedient to follow the method prescribed in other sciences of like nature, and to study the present vegetation of our earth, as the best means of learning that of the past. The following sketch will afford an outline of the classification of the vegetable kingdom, and for more ample details we would refer to the admirable Introductions to

Botany, by Sir William Hooker, Sir J. E. Smith, Dr. Lindley, &c.

The arrangement of Jussieu, and, after him, of De Candolle, in his *Théorie Elémentaire*, which is usually termed the Natural System, is that generally adopted by botanists. According to this system, plants are classified into two great divisions. The first, and most simple, consists of those which are composed entirely of cellular substance, are wholly destitute of vessels, and the embryo, or germ of which has no cotyledons, or seed-leaves, whence they are termed cellular, or *acotyledonous* plants; they are also named *cryptogamic*, from κρυπτος, and γαμος, concealed marriage, because they have no parts of fructification, or rather, since none have ever yet been discovered. The other division comprises such as are more complicated in structure, being furnished with a cellular substance and tubular vessels, and the embryo having one or more *cotyledons*, or seed-leaves, whence they are called vascular or *cotyledonous* plants, and are again subdivided into the *dicotyledonous*, or *exogenous*, and the *monocotyledonous*, or *endogenous* classes.

Exogenous or Dicotyledonous Structure.—These two subdivisions are well exemplified by the oak and the cane, specimens of which may easily be procured for comparison. A transverse section of the former exhibits a central, cellular substance or pith; an external cellular and fibrous ring, or bark; an intermediate woody mass, and certain fine lines, radiating like the spokes of a wheel, from the pith to the bark through the wood, and called medullary rays.

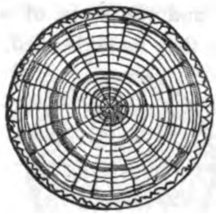


FIG. 132.—Transverse section of dicotyledonous wood.

This is the structure of an *exogenous* plant, so called from εξω, without, and γενναω, to increase, because its mode of growth is by fresh layers from without, from the circumference to the centre; it is also termed *dicotyledonous*, because its germ has two *cotyledons*, or seed-leaves.

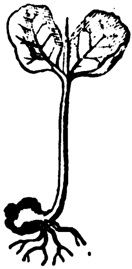


FIG. 133.—Germ of dicotyledonous plant.

Plants of this kind compose the greater part of our European trees, and their leaves have nerves much branched and running into each other.

ENDOGENOUS OR MONOCOTYLEDONOUS STRUCTURE.—In the cane, on the contrary, neither bark nor pith, nor wood, nor medullary rays, are distinguishable; but the transverse section exhibits a large number of holes, irregularly arranged, and caused by the section of

vessel-like tissue, and the mass of woody or cellular substance in which they lie embedded.

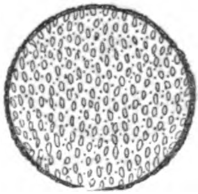


FIG. 134.—Transverse section of monocotyledonous wood.

A longitudinal section exhibits similar differences, as

FIG. 135.
Longitudinal section of dicotyledonous wood.

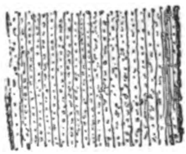


FIG. 136.
Longitudinal section of monocotyledonous wood.

Plants of this latter class are called *endogenous*, from *ενδον*, within, and *γενναω*, to increase, because their growth takes place from within, from the centre to the circumference; they are also styled *monocotyledonous*, because the germ has but one *cotyledon*, or seed-leaf.

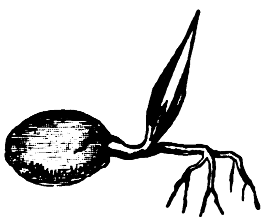


FIG. 137.—Germ of monocotyledonous plant.

Trees of this class prevail most abundantly in tropical climates, and their leaves exhibit nerves which run parallel to each other. So constant are the characters of the two kinds of venation in the leaves, that the experienced botanist, on inspecting the mere fragment of a leaf, is able to distinguish the *dicotyledonous* nature of a plant from the fibrous interlacing of its vessels, as seen in the apple,

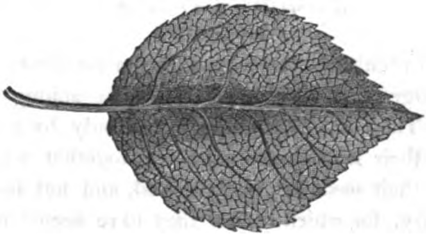


FIG. 138.

or the *monocotyledonous* character in the smooth and parallel veins of the *gloriosa superba.*

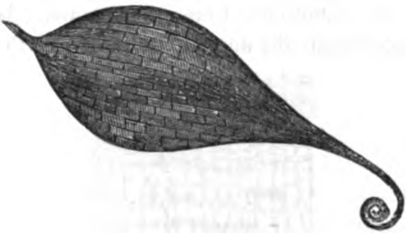


FIG. 139.

CONIFEROUS PLANTS.—In some families of the *dico-*

tyledonous class, the cells, or tubes, are marked with spots or glands.

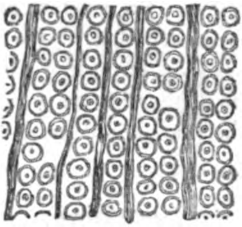


FIG. 140.

This is peculiarly the case with the *coniferæ*, which form a large and very important tribe among living plants. They are characterized not only by peculiarities in their fructification, having, together with the *cycadeæ*, their seeds originally naked, and not inclosed in an ovary, for which reason they have been arranged as a distinct order; but they are still farther distinguished by the peculiarity in their woody structure above-mentioned, whereby the smallest fragment can readily be identified. A transverse section of any coniferous wood, in addition to the radiating and concentric lines, exhibits a system of reticulations by which *coniferæ* are distinguishable from other plants. The cross-lines *a*, *a*, indicate the annual circles of growth.

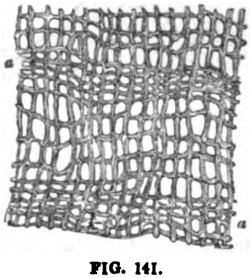


FIG. 141.

Among other characteristics of trees of this family, they all secrete resin, have branched trunks, and linear, entire, rigid leaves, and they occur both in the hottest and coldest regions. It should be observed that the varied structures of wood described as above, are best and most clearly seen by the aid of the microscope.

Investigation of Fossil Plants. — The object chiefly desired by the student of fossil botany, is to acquire such a degree of knowledge as will enable him to determine a fossil plant with facility and correctness, and to refer it to the genus and species to which, if already known, it legitimately belongs. The remarks of Dr. Lindley and M. Brongniart on these points, are so able and instructive, that we shall beg to transfer to our pages the substance of their observations.

It is observed, that while, in recent plants, the botanist has the opportunity of examining the organs both of fructification and vegetation taken together; and, from their structure is enabled to judge of the class, order, or genus to which the specimen belongs; in a fossil plant, the only parts capable of being examined are the internal structure of the stem, and its external surface, together with the position, division, outline, and veinings of the leaves; while it has never yet occurred that any one specimen has afforded the whole, and, in general, it is only two or three of these characters which the botanist can employ.

Thus if the subject of inquiry be a fragment of the fossil trunk of some unknown tree, if no trace can be ascertained of its exact anatomical structure, it may be possible, at least, to ascertain whether its wood was deposited in concentric zones, or in a confused manner; in the former case it would have been dicotyledonous,

or exogenous; in the latter, monocotyledonous, or endogenous; if a transverse section should show the remains of sinuous unconnected layers, resembling arcs, or parts of a circle, with their ends outwards, of a solid homogeneous character, and embedded among some softer substance, then it may be considered certain that such a stem belonged to some tree-fern. If the tissue is altogether cellular, and it can be satisfactorily ascertained that no vascular tissue is combined with it, the specimen, in all probability, has belonged to that division of the vegetable kingdom, which, being propagated without the agency of sexes, is termed *cryptogamiæ;* care being observed to examine it rigorously, lest it prove a succulent portion of some dicotyledonous tree, in which the vascular system is so scattered among cellular substance as to be scarcely discernible. If the tissue consists of tubes placed parallel with each other, without any trace of rays passing from the centre to the circumference, it is endogenous, even if there be an appearance of concentric circles in the wood; but if any trace whatever can be discovered of tissue crossing the longitudinal tubes at right angles, from the centre to the circumference, such a specimen is exogenous, whether concentric circles can be made out or not; for such an arrangement of tissue would indicate the presence of medullary rays, which are the most certain sign of a dicotyledonous plant. If, in a specimen having these medullary rays, the longitudinal tubes are all of the same size, a circumstance obvious upon the inspection of a transverse section, the plant is either coniferous or cycadeous; but if among the smaller tubes, which, in fact, are woody fibres, some larger ones are interspersed *in a definite manner*, in that case it belongs to

some other tribe of dicotyledons. It is indispensable that the arrangement of the larger tubes should be *definite*, for appearances of the same kind exist in most coniferous wood; but in the latter they are scattered in an *indefinite* manner, among the smaller tubes, and are not vessels, but cylindrical cavities for the collection of the resinous secretions peculiar to the fir-tribe. And if the walls of the longitudinal tubes of any fossil specimen are found to exhibit appearances of little warts, or excrescences growing from their sides, such a specimen is to be referred to some coniferous, or cycadeous plant, as no other tribes of vegetation present such a structure. If a trace of pith can be discovered, that circumstance alone will prove the plant to be dicotyledonous, because all other classes are destitute of that central, cellular column, it being remembered, at the same time, that as the roots of dicotyledonous plants are destitute of pith, the absence of pith does not prove the plant not to have been of that order, as the part examined may have been a portion of the root.

If a stem is in such a state that nothing can be determined respecting its anatomy, it will be necessary to judge of it by another set of characters. In the first place, it should be inquired whether it had a distinctly separable bark; in the second, if it had a cortical integument that differed, in its organization, from the wood, without being separable from it; or, thirdly, if it possessed neither the one nor the other. In the first place it would have been dicotyledonous; in the second, monocotyledonous; in the third, acotyledonous, or cryptogamic, supposing it had been a trunk which many successive years had contributed to form. The distinction, as applied to the two latter classes, is not,

however, so positive as could be wished, because tree-ferns have a cortical integument; but they are easily known by the long ragged scars left by their leaves; and no other cryptogamic plants possess the character of having a spurious bark.

A third, and very important kind of evidence, is to be collected from the scars left upon stems by the fall of the leaves. Although these will neither inform us of the shape, nor other characters of the leaves themselves, yet they indicate with precision their position, the form of their base, and sometimes also their probable direction: we can tell whether they were opposite or verticillate, alternate or spirally disposed, deciduous or persistent, imbricated or remote, all characters of great use as means of discrimination, and as frequently affording important negative evidence on doubtful points.

Care must be taken, as Adolphe Brongniart cautions, not to mistake, for different species, those stems which still retain their cortical integument, as distinguished from such as have lost it. In the two cases the appearance of the scars will be different; those of the former being more rounded, broader, and more deeply furrowed than the latter; for the one is a real scar, showing the outline of the base of the leaf, while the latter is solely caused by the passage of vessels out of the stem into the petiole or footstalk of the leaves.

In leaves we can rarely recognise, in a fossil state, more than their mode of venation, division, arrangement, and outline, to which are sometimes added their texture and surface. All these are of importance, but in unequal degrees. The distribution of the veins, taken together with the mode of division of a leaf,

affords evidence of the highest value. If the veins are all parallel, unbranched, or only connected by little transverse bars, and the leaves undivided, the plant was probably monocotyledonous; and if the veins of such a leaf, instead of running side by side, from the base to the apex, diverge from the mid-ribs, and lose themselves in the margin, forming a close series of double curves, the plant was certainly analogous to what are now called *scitamineæ*, or *marantaceæ*, or *musaceæ*; but supposing that the parallel arrangement of simple veins is combined with a pinnated foliage, then the plant would probably have belonged to *cycadeæ*, that curious tribe which stands on the very limits of monocotyledonous and dicotyledonous, and of flowering, and flowerless plants.

If the veins are all of equal thickness, and dichotomous, we have an indication of the fern tribe, which is seldom deceptive. Nevertheless, it must be remembered that the flabelliform leaves, both of monocotyledons and dicotyledons, have occasionally this kind of venation. Even if the veins are not dichotomous, if they are all of nearly equal thickness, and very fine, or divided in a very simple manner, it is probable that they indicate the fern tribe, whether simple, as in the fossil genus *tæniopteris*, or reticulated, as in the modern genus *meniscium*. If the veins are of obviously unequal thickness, and so branched as to resemble the meshes of a net, we have a sign of dicotyledonous structure that seldom misleads us. Finally, if no veins at all are to be found, an opinion must be formed, not from their absence, but from other circumstances. If the leaves are small, their absence may be due to incomplete developement, but if they are large and irregularly

divided, we may have an indication of some kind of marine plant. When the leaves are small and densely imbricated, they are generally considered by botanists to belong to either *lycopodiaceæ* or *coniferæ;* but there is so little to distinguish these families in a fossil state, that there is scarcely any means of demonstrating to which of these such genera as *lycopodites, lycopodendron, juniperites, taxites,* &c., and the like, actually belong.

ARRANGEMENT OF FOSSIL PLANTS.—M. Adolphe Brongniart has divided the vegetation of the ancient earth into four distinct periods. His first commences with the earliest traces of vegetable life, and terminates with the carboniferous epoch; the second concludes with the saliferous, or new red sandstone system; the third comprises the oolite and chalk; and the fourth the tertiary period. He has published, in his *Prodrome d'une Histoire des Végétaux Fossiles,* the following comparative table of the extinct and living classes of plants.

	First Period.	Second Period.	Third Period.	Fourth Period.	Living.
Agamiæ	4	5	18	13	7000
Cryptogamiæ cellulosæ . .				2	1500
——— vasculosæ . .	222	8	31	6	1700
Phanerogamiæ gymnospermiæ .		5	35	20	150
Monocotyledoniæ	16	5	3	25	8000
Dicotyledoniæ				100	32000
Indeterminate	22				

This table has now been published some years, during which several new species have been discovered; but the general proportions are conceived to be still unchanged.

REMARKS OF COUNT STERNBERG.—These four periods

Count Sternberg reduces to three, by uniting the second and third of Brongniart into one. These three periods have been termed, the first, that of islands, the second of coasts, and the third of continents. This distinguished German *savant* offers the following among other remarks, illustrative of these various epochs.

The flora of the first era, he observes, terminating with the coal, was simple, but magnificent, and extremely elegant in its forms, consisting of plants which either have no existing analogues at the present moment, or such as are now limited to the torrid zone. The accompanying illustration depicts the character of these plants.

Vegetation of the coal.

a Arborescent fern.
b Pecopteris.
c Asterophyllites.
d Neuropteris.
e Lepidodendron.
f Calamites.
g Araucaria.
h Casuerina.

FIG. 142.

That of the second, (comprising the second and third of Brongniart,) presents few analogies of genus, and probably none of species, with those of the period preceding; and thus the first flora which, he adds, was universally diffused over the whole earth, was strongly distinguished, (*scharf abgeschnitten*) from the second. The annexed engraving pourtrays the flora of the saliferous, oolitic, and wealden systems.

Vegetation of the oolitic period.

a Arborescent fern, peculiar species. *c* Pandanus.
b Cycas and zamia. *d* Palmi.

FIG. 143.

The second was not separated in so marked a manner from the succeeding, but passed imperceptibly into the third, (the fourth of Brongniart,) which comprises the tertiary formations, and is only to be distinguished, in a botanical point of view, he observes, by the change in the relative numbers of acotyledonous and monocotyledonous, as compared with dicotyledonous plants,

as well as by the more European character of its entire vegetation.

OF DR. LINDLEY.—The observations of Dr. Lindley, on the successive periods, adopted by Brongniart, are in substance as follows:—

In the first, comprising the coal formation, he remarks that the flora of that era consisted of ferns in vast abundance; of large coniferous trees; of species resembling *lycopodiaceæ*, but of most gigantic dimensions; of vast quantities of a tribe apparently analogous to *cacteæ*, or *euphorbiaceæ*, but perhaps not identical with them; of palms and other monocotyledons; and, finally, of numerous plants, the exact nature of which is extremely doubtful. Of the entire number of species detected in this formation, two-thirds are ferns.

In the new red sandstone formation, the characters of vegetation are altered by the disappearance of the *cacteæ*, or *euphorbiaceæ*, by a diminution of the proportion of ferns, and by the appearance of a few new tribes; but, he remarks, so little is known of the flora of this period, that it is scarcely worth noticing as a distinct epoch, but might more appropriately be classed (as Count Sternberg has, in fact, arranged it,) with the period succeeding.

In the lias and oolite formations, an entirely new race of plants covered the earth. The proportional number of ferns is here diminished: the gigantic lycopodium-like, and cactoid plants of the coal measures, the *calamites* and palms all disappear; but species, undoubtedly, belonging to *cycadeæ*, and analogous to plants now natives of the Cape of Good Hope and New Holland, appear to have been common. Coniferous plants were still prevalent, but they were of species which did not exist at an earlier period.

Up to this time, the features of vegetation were extra-European, and chiefly tropical, but immediately succeeding the chalk, a change analogous to that observable in the animal kingdom took place. The early deposits of this period are characterised by a total absence of *cycadeæ;* the number of ferns is strikingly diminished, and *coniferæ* increase in quantity; while mixed with palms and other tropical monocotyledons, there grew elms, willows, poplars, chesnuts, and sycamores, together with numerous other dicotyledonous plants, which increased in number and variety, till the flora of the most recent of the tertiary deposits has nothing to distinguish it from that of the present day.

Celebrated Experiment of Dr. Lindley.—The great preponderance of ferns, and of the higher order of cryptogamic plants, in the flora of the ancient earth, having excited, in a peculiar degree, the attention of naturalists, and it being conceived that the total absence of certain kinds of plants, and the constant presence of others, with other points of like nature and interest, might be accounted for by a difference in the capability of one plant beyond another of resisting the action of water, Dr. Lindley resolved on trying the result of an actual experiment. He, therefore, on the 21st of March, 1833, filled a large iron tank with water, and immersed in it 177 specimens of various plants, belonging to the more remarkable natural orders, taking care, in particular, to include representatives of all those which are either constantly present in the coal-measures, or as universally absent. The vessel was placed in the open air, left uncovered, and was untouched, with the exception of filling up the water as it evaporated, till the 22nd April, 1835, that is, for rather

more than two years. At the end of that time what remained was examined, when the following highly important results were obtained.

In the first place, it was found that the dicotyledonous plants, in general, had wholly disappeared, whence it was inferred, that they were unable to remain for two years in water without being totally decomposed; the principal part of those which did possess that power appeared to be *coniferæ* and *cycadeæ*, which are precisely those which we find best preserved in a fossil state. Secondly, it seemed that monocotyledons survived to a considerable extent, whence it was concluded that they are more capable of resisting the action of water, in particular, palms and scitamineous plants, which are what we principally find as fossils; but that grasses and sedges perished; whence it was inferred that we have no right to assume that the earth was not originally clothed with grasses, because we no longer find their remains; thirdly, that fungi and mosses, and all the lowest forms of vegetation disappeared, and that even *equisetum* left no traces behind; and, finally, that ferns appeared to have a great power of resisting water if gathered in a green state, not one of them having disappeared during the experiment; but that the effect of immersion in water was to cause their fructification to rot away; a result which we constantly meet with in the fossil specimens.

Hence, Dr. Lindley assumes, as a general result, that the numerical proportion of different families of plants, found in a fossil state, throws no light whatever upon the ancient climate of the earth; but depends entirely upon the power which particular families may possess, by virtue of the organization of their cuticle, of resisting

the action of the water in which they floated, previously to their being finally fixed in the rocks in which they are now found.

In addition to these statements, it may be remarked, that the most striking argument hitherto offered against the existence of dicotyledonous plants at this period, appears to be; that inasmuch as we are justified in supposing that the circumstances under which the plants of the coal were entombed, were analogous to those which attended the submergence of those of the tertiary period, we should find that, if dicotyledonous plants had existed at the carboniferous epoch, in any considerable numbers, they would have left their impression on the shales, in the same manner as the tertiary plants have constantly left their imprints on the deposits of that date.

On the other hand, if, as is now generally assumed, we consider the *sigillariæ* to be of the dicotyledonous class, we shall, at all events, by the addition of this extensive genus, acquire a much larger numerical proportion of plants of this order, than was conceived up to a very recent period to have existed at this epoch.

OBJECTIONS OF COUNT STERNBERG.—The whole subject, however, is replete with difficulties, such as the present state of our knowledge by no means enables us to explain, and Count Sternberg suggests the following contradictions and anomalies as arising out of the experiment just described. He fully admits the antiseptic quality of ferns, which, he remarks, had previously been demonstrated in the shipwreck experienced by the late M. Dumont d'Urville, in which his plants having been submerged, and afterwards recovered, the grasses and ferns were saved, while the dicotyledon-

ous plants were wholly lost. He next observes, that it would seem that the *equisetaceæ* were all destroyed; yet, he remarks, they are excellently preserved in the period extending from the carboniferous to the chalk formation; while, on the other hand, the ferns of the tertiary flora must have also perished, since we are acquainted but with three from the brown coal, though it cannot be supposed that none were submerged in those deposits, seeing that they constitute the majority of the plants of the extensive era from the coal to the chalk, and are also abundant at the present day. In conclusion, he suggests the probability, that the experiments of Dr. Lindley having been made with pure water, may not have produced precisely the same chemical effects on the plants, as was the case with those of the coal, which were immersed in water so impure and admixed, as to have deposited the clay-slate in which they are preserved.*

CLASSIFICATION OF PLANTS.—We shall now proceed to describe the arrangement of the vegetable kingdom in detail, and shall offer a brief description of those fossil plants which are most familiar, and of most frequent occurrence, under the classes to which they are separately referred.

The whole vegetable realm is divided, by M. Adolphe Brongniart, into six grand classes.

1. The agamiæ.
2. The cellular cryptogamiæ.
3. The vascular cryptogamiæ.
4. The gymnosperm phanerogamiæ.

* See Flora der Vorwelt, p. 83.

5. The monocotyledonous phanerogamiæ.
6. The dicotyledonous phanerogamiæ.

The following are the observations of M. Brongniart, explanatory of the above arrangement:—

"The first class is that of the *agamiæ*, a term which, however, we may consider as possibly expressing only our ignorance. This class comprises the different families confounded under the names of *algæ*, *fungi*, and *lichens*. The characters common to all these vegetables are as follows: they are entirely formed of cellular tissue, or rather of interlacing tubular filaments, without vessels properly so called; they never present true leaves, and their organs of reproduction consist only of very fine seedlings, which appear to develope themselves without fecundation, and are immediately inclosed in membranous conceptacles analogous to the filaments of that tissue which composes the whole of the plant. The only fossil plants of this class known are some *confervæ* with several *algæ*.

"The second class, that of the cellular *cryptogamiæ*, comprises the two families of *hepaticæ* or liverworts, and *musci*, or mosses; their organs of vegetation, although solely composed of cellular tissue, offer, in most cases, leaves well characterised by their form, their structure, and by the fact that they are similar to those of the most perfect vegetables. Their organs of reproduction present a more complicated structure; there are sexual organs very distinct, which have been perfectly described by Hedwig; the seedlings are contained in conceptacles of very complex organization. One fossil plant only is known as appertaining to this class.

"The third class, that of the *vascular cryptogamiæ*, includes those vegetables, the more varied tissues of

which almost always include perfectly distinct vessels, and very frequently spiral vessels or imperfect spiral vessels, while the leaves are in general very fully developed, and furnished with cortical pores; the stems, which are often large and arborescent, have some analogy by their structure with that of *monocotyledons;* and finally, the organs of reproduction always appear to consist of two distinct sexes, which produce seedlings inclosed in conceptacles of a somewhat complicated organization. To this class belong the *equisetaceæ*, the ferns, the *lycopodiaceæ*, the *marsiliaceæ*, and the *characeæ*.

"In the fourth class, under the name of *phanerogamic gymnosperms*, we unite the two remarkable families of *cycadeæ* and *coniferæ*, which really cannot be confounded by associating them in either of the other classes with vegetables, from which they are so distinct by the structure of their organs of reproduction, since their seeds, being destitute of capsules, receive directly the action of the fecundating substance; and from which they are also distinguished by the organization of their stems, which differ in many respects from those of true *dicotyledons*.

"Finally, the fifth and sixth classes are formed of *phanerogamic monocotyledons* and *dicotyledons*, as they are defined by all botanists, omitting only the two families composing the preceding class.

"If, on the one hand, the above arrangement presents but little uniformity in the relative extent of the six grand primary divisions here described, three of them, the *agamiæ*, the *monocotyledons*, and *dicotyledons*, comprising a considerable number of families, genera, and species, while the remainder, in particular the

fourth, include only a very limited number; on the other hand, we preserve a far more essential uniformity in the importance of the characters; the groups which we obtain are, moreover, perfectly natural, and we do not meet with those contradictory disparities which it is impossible to avoid in dividing the vegetable kingdom only into three grand classes."

We subjoin, for the sake of clearness, a tabular arrangement of the various families which compose the classes above mentioned.

Class I.—AGAMIÆ.

1st Family.—Confervæ.
2nd Family.—Algæ.

Class II.—CELLULAR CRYPTOGAMIÆ.

3rd Family.—Mosses and Liverworts.

Class III.—VASCULAR CRYPTOGAMIÆ.

4th Family.—Equisetaceæ, the horse-tail tribe.
5th Family.—Ferns.
6th Family.—Marsiliaceæ, the pepper-wort tribe.
7th Family.—Characeæ, the chara tribe.
8th Family.—Lycopodiaceæ, the club mosses.

Class IV.—PHANEROGAMIC GYMNOSPERMS.

9th Family.—Cycadeæ.
10th Family.—Coniferæ, the fir tribes.

CLASS V.—MONOCOTYLEDONOUS PHANEROGAMIÆ.

11th Family.—NAIADES.
12th Family.—PALMS.
13th Family.—LILIACEÆ, the lily tribe.
14th Family.—CANNEÆ.

CLASS VI. — DICOTYLEDONOUS PHANEROGAMIÆ.

15th Family.—AMENTACEÆ, the birch tribe.
16th Family.—JUGLANDEÆ, the walnut tribe.
17th Family.—ACERINEÆ, the sycamore tribe.
18th Family.—NYMPHACEÆ, the water-lily tribe.

CLASS I. AGAMIÆ.

The first class, that of *agamiæ*, so called from *a* privative, and *γαμος*, marriage, because no organs have been discovered which distinguish them as male and female flowers, comprises, as before stated, the first family, that of the *confervæ*, and the second that of the *algæ*, or sea-weeds, some few of each being found in a fossil state. We subjoin from Brongniart a figure of *fucoides targionii* discovered by Dr. Mantell in the glauconite, or fire-stone of the chalk formation.

FIG. 144.

Class II.—CELLULAR CRYPTOGAMIÆ.

The second class, that of the *cellular cryptogamiæ*, includes the third family, that of the liverworts and mosses.

Class III.—VASCULAR CRYPTOGAMIÆ.

The third class, that of the higher order of cryptogamous plants, entitled *vascular cryptogamiæ*, constitutes the bulk of the plants of the coal, and comprises the extensive tribes of the *equisetaceæ*, or horse-tail family; the ferns; the *marsiliaceæ*, or pepper-wort family; the *characeæ*, or chara family; and the *lycopodiaceæ*, or the club mosses. But, though resembling the recent tribes above-mentioned, the fossil plants far surpass them in size and grandeur. Thus the *equisetum*, or horse-tail, is a small and slender but elegant plant of our ponds and ditches, not more than half an inch in diameter, having a succulent, erect, and jointed stem, with verticillate fringes of linear leaves growing round

the joints, and bearing spikes of fructification on the summit. Plants of this order are abundant in the coal; but they are, comparatively, of gigantic species, exceeding a foot in circumference.

4th Family.—Equisetaceæ.

We subjoin a figure of the existing *equisetum*,

FIG. 145.

with that of the fossil *equisetum columnare*, from the work of Brongniart, and of *calamites cannæformis*, another genus of this order, from that of Lindley and Hutton.

FIG. 146.—Equisetum columnare. Br. Pl. 120.

FIG. 147.—Calamites cannæformis. Schlot.

5th Family.—Ferns.

We next arrive at the ferns, which form so large a proportion of the plants of the coal, and which, like the tribes just mentioned, present in their stupendous size and proportions so striking a contrast to their diminutive analogues of this climate at the present day. The common brake or fern of our commons and waste lands exhibits a type of the family; but the arborescent ferns which now grow only in the vicinity of the equator present the closest analogy to the ferns of the carboniferous system, which were lofty trees, far surpassing in height and magnificence even their tropical representatives of the existing era. A splendid specimen, that of the *alsophila brunoniana*, which is placed on the staircase of the British Museum, affords an idea of the present arborescent ferns of the tropics, which attain an elevation of forty or fifty feet, their stems being marked with scars, from the decay of the leaf-stalks, and their summits covered with a spreading dome of graceful foliage. The scars somewhat resemble those of other monocotyledonous plants, especially the palms, but differ in the circumstance that in the ferns they are commonly longitudinal, (longer than wide,) while, in the palms, they are transverse, (wider than long). From their number, variety, and from the presumed antiseptic property of their cuticle, already mentioned, they afford some of the most instructive and interesting fossil remains which the vegetable kingdom has produced. Their leaves are elegant, displaying the utmost variety in their shape, and the greatest diversity in the veins of the leaf; and it is from these characters that naturalists have formed the generic and specific distinctions of the entire family. They are often pre-

served in the utmost perfection, and even the parts of fructification are occasionally observable at the back of the leaf.

The fossil ferns are divided into the following genera, which are all determined by the character of their fronds or leaves:—*pachypteris*, *sphenopteris*, *cyclopteris*, *glossopteris*, *neuropteris*, *odontopteris*, *anomopteris*, *tæniopteris*, *pecopteris*, *lonchopteris*, *clathropteris*, *schizopteris*, *otopteris*, *caulopteris*, *and sigillaria*, *&c.*, the two latter occurring only as stems; and the last, as we have before mentioned, being considered by recent inquirers as a dicotyledonous plant.

We shall now offer a description of each genus of most frequent occurrence, with the figure of a typical species of each.

Pachypteris, from παχυς, thick, and πτερις, a fern.

Leaves pinnated, or bipinnated, leaflets entire, coriaceous, ribless, or one-ribbed, contracted at the base, but not adherent to the mid-rib.

Two species only have been discovered; in the oolite formation.

The following is a figure of *P. lanceolata*, from Brongniart, Pl. 45.

FIG 148.

Sphenopteris, from σφην, a wedge, and πτερις, a fern, the generic characters of which are as follow :—

Leaves bi-tripinnatifid ; leaflets contracted at the base, not adherent to the rachis. Lobed ; the lower lobes largest, diverging, somewhat palmate ; veins bipinnate, radiating, as it were, from the base.

We give, as an example, the *S. crenata*, from Lindley and Hutton, Pl. 39. The species amount to about thirty-six.

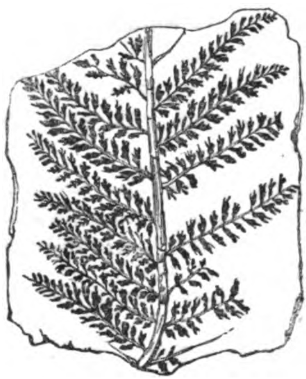


FIG. 149.

Cyclopteris, from κυκλος, a circle, and πτερις, a fern.

Leaves simple, entire, and somewhat orbicular ; veins numerous, radiating from the base, dichotomous, equal ; mid-rib wanting.

One species in the transition rocks.

Four species in the coal.

One species in the oolitic formation.

We add a figure of *C. Beanii*, from Lindley and Hutton, Pl. 44.

FIG. 150.

Glossopteris, from γλωσσα, a tongue, and πτερις, a fern.

Leaves simple, entire, somewhat lanceolate, narrowing gradually to the base, with a thick vanishing midrib; veins oblique, curved, equal, frequently dichotomous, or sometimes anastomosing, and reticulated at the base.

Two species in the coal.
One species in the lias.
One species in the oolite formation.

The subjoined illustration depicts *G. Phillipsii*, from Lindley and Hutton, Pl. 63.

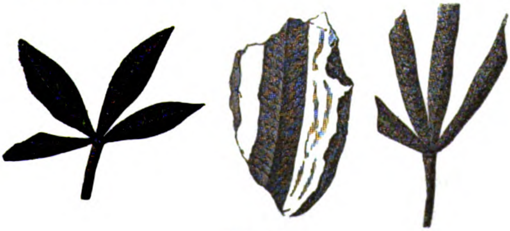


FIG. 151.

Neuropteris, from νευρον, a nerve, and πτερις, a fern.

Leaves bipinnate, or rarely pinnate ; leaflets, usually, somewhat cordate at the base, neither adhering to each other, nor to the rachis by their whole base, only by the middle portion of it; mid-rib vanishing at the apex; veins oblique, curved, very fine, dichotomous. Fructification; sori lanceolate, even, covered with an indusium, arising from the veins of the apex of the leaflets, and often placed in the bifurcations.

Twenty-four species in the coal formation.
Three species in the new red sandstone.
One species in the anthracite of Savoy.
One species in the muschelkalk.

We subjoin a figure of *N. Loshii*, with a magnified leaflet, from Lindley and Hutton, Pl. 49.

FIG. 152.

Odontopteris, from οδους, a tooth, and πτερις, a fern.

Leaves bipinnated; leaflets membranous, very thin, adhering by all their base to the rachis, with no, or almost

no mid-rib; veins equal, simple, or forked, very fine, most of them springing from the rachis.

Five species in the coal formation.

We subjoin a figure of *O. minor*, from Brongniart, Pl. 77.

FIG. 153.

Anomopteris, from *α* privative, *νομος*, a law, and *πτερις*, a fern.

Leaves pinnated; leaflets linear, entire, somewhat plaited transversely at the veins, having a mid-rib; veins simple, perpendicular, curved. Fructification arising from the veins, uncertain as to form; perhaps dot-like, and inserted in the middle of the veins; or perhaps linear, attached to the whole of a vein, naked as in *meniscia*, or covered by an indusium, opening inwardly.

One species in the new red sandstone.

Tæniopteris, from *ταίνια*, a fillet, or wreath, and *πτερις*, a fern.

Leaves simple, entire, with a stiff, thick mid-rib; veins perpendicular, simple, or forked, at the base. Fructification dot-like.

Three species in the lias and oolite formations.

We add a figure of *T. vittata*, together with a magnified leaflet, from Lindley and Hutton, Pl. 62.

FIG. 154.

Pecopteris, from a word unknown to the author, and πτερις, a fern.

Leaf once, twice, or thrice pinnate; leaflets adhering by their base to the rachis, or occasionally distinct; mid-rib running quite through the leaflet; veins almost perpendicular to the mid-rib, simple, or once, or twice dichotomous.

Sixty species in the coal formation.
Two species in the lias.
Ten species in the oolite.
One species in the beds above the chalk.

The accompanying figure is that of *P. adiantoides*,

with magnified leaflet; also from Lindley and Hutton, Pl. 37.

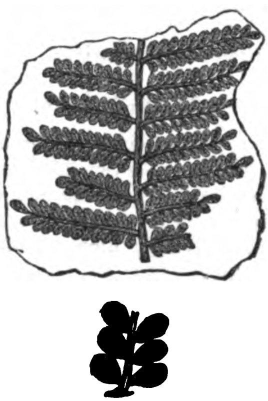


FIG. 155.

Lonchopteris, from λογχος, a spear, and πτερις, a fern.

Leaf many times pinnatifid; leaflets more or less connate at the base, having a mid-rib; veins reticulated.
Two species in the coal formation.
One species in the green sand formation.

Clathropteris, from κλειθρον, a lattice, and πτερις, a fern.

Leaf deeply pinnatifid; leaflets having a very strong complete mid-rib; veins numerous and simple, parallel, almost perpendicular to the mid-rib, united by transverse veins, which form a net-work of square meshes upon the leaf.

One species in the lias.

Schizopteris, from σχιζα, a fissure, or division, and πτερις, a fern.

Leaf linear, plain, without mid-rib, finely striated,

almost flabelliform, dividing into several lobes, which are linear and dichotomous, or rather irregularly pinnated and erect, lobes dilated and rounded towards the extremity.

One species in the coal formation.

Otopteris, from *ους*, an ear, and *πτερις*, a fern.

Leaf pinnated; leaflets originating obliquely from the side of the leaf-stalk, auricled, attached by about half their base, destitute of all trace of mid-rib. Veins of equal size very closely arranged, diverging from their point of origin and dividing dichotomously at an exceedingly acute angle.

We subjoin a figure of *O. acuminata*, from Lindley and Hutton, Pl. 132.

FIG. 156.

Caulopteris, from *καυλος*, a stem, and *πτερις*, a fern.

This is a term formed to describe those stems which,

from their markings, are considered by Dr. Lindley to be true stems of ferns; those figured or described as being so by Sternberg, Brongniart, and others, under the name of *sigillaria*, *favularia*, &c., not being now regarded as such.

6th Family.—Marsiliaceæ, or Pepperwort Tribe.

This family comprises the doubtful genus.

Sphenophyllum, rotularia, of Sternberg.

Branched, deeply furrowed; leaves verticillate, wedge-shaped, with dichotomous veins.
Eight species in the coal formations.

7th Family.—Characeæ, or Chara Family.

Chara, gyrogonites, of Lamarck.

Fruit oval, or spheroidal; consisting of five valves, twisted spirally, a small opening at each extremity; stems friable, jointed, composed of straight tubes, arranged in a cylinder.
Five species in the tertiary formations.

8th Family.—Lycopodiaceæ, or Club-mosses.

Lycopodites, lycopodiolithus, and walchia of Sternberg.

Branches pinnated; leaves inserted all round the stem in two opposite rows, not leaving clean and well-defined scars.
Ten species in the coal formation.
One species in the sandstone of the lias.
One species in the inferior oolite.
One species in the marl below the chalk.

The accompanying figure delineates *L. Williamsonis*, together with a cone and magnified leaflet, of Lindley and Hutton, Pl. 93.

Cone.

Magnified leaflet.

FIG. 157.

Selaginites.

Stems dichotomous, not presenting regular elevations at the base of the leaves, even near the lower end of the stems. Leaves often persistent, enlarged at their base.

Two species in the coal formation.

Lepidodendron, from λεπις, a scale, and δενδρον, a tree, sagenaria, of Sternberg.

Stems dichotomous, covered near their extremities by simple linear or lanceolate leaves, inserted upon rhomboidal areolæ; lower part of the stems leafless; areolæ longer than broad, marked near their upper part by a minute scar, which is broader than long, and has three angles, of which the two lateral are acute; the lower obtuse, the latter sometimes wanting.

Several species in the coal formation.

Ulodendron.

Stem covered with rhomboidal areolæ, which are broader than long; scars large, few, placed one above the other, circular, composed of broad cuneate scales, radiating from a common centre, and indicating the former presence of organs, that were, perhaps, analogous to the cones of *coniferæ.*

Two species in the coal measures.

Lepidophyllum.

This term signifies leaves, which it is conceived may have belonged to *lepidodendron;* they are sessile, simple, entire, lanceolate, or linear, traversed by a single midrib, or by three parallel ribs. No veins.

Lepidostrobus.

This name indicates cones ovate, or cylindrical, composed of imbricated scales, inserted by a narrow base around a woody axis; their points sometimes dilated and reversed in the form of rhomboidal disks. Seed solitary, oblong, and winged, nearly as long as the scales.

Five species in the coal formation.

We subjoin a figure of *L. ornatus.*

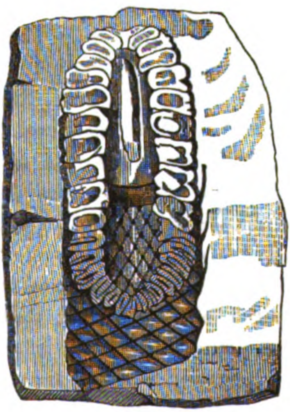


FIG. 158.

These cones are commonly conceived to have been those of *lepidodendron;* but we are indebted to Mr. Hawkshaw for the fact, that beneath each of the magnificent, erect fossil trees, discovered by him on the Bolton and Manchester Railway, a number of these cones were found lying in such a position as indicated their having fallen from the tree. Corda, a German botanist, declares them to be the male flowers of *coniferæ.* The trees were pronounced by the late Mr. Bowman to be *sigillariæ.*

Professor Corda, in a Supplement to his Sketches of the Anatomy of Stems, has some farther observations on the *lepidostrobi.* He considers them as divisible into three forms, the first comprising *L. pinaster*, Foss. Flo. fig. 198; and *L. ornatus* var-*didymus*, Foss. Flo. fig. 163. These he regards as fragments of stems, referring *L. pinaster* to Presl's genus of *lycopodites*, *Bergera pinaster*, and *L. ornatus* to *Cycadites ornatus.* The second form includes *L. ornatus*, Foss. Flo. fig. 26, which he considers as a fruit of yet unknown and problematical kind; while the third comprises what he recognises as true *lepidostrobi*, viz. *L. variabilis*, Foss. Flo. fig. 10, *L. comosus*, Foss. Flo. fig. 162, and the specimens so splendidly figured by Brongniart, vol. ii. fig. 22 and 23. He adds, that these last will require more investigation than the two preceding forms, and that to ascertain their structure and assign their due character and position, it will be advisable, at the same time, to take up the investigation of the fruit of *lycopodiaceæ*, with which they are compared by Brongniart; then to determine their peculiar structure, and to compare it with those groups and families to which they are referred above.

Cardiocarpon, from καρδιον, the heart, and καρπος, fruit.

These are heart-shaped fruits, five species of which occur in the coal formation.

Stigmaria. Variolaria, Sternb.; mammillaria, Brongn.; ficoidites, Artis.

Stem originally succulent; marked externally by roundish tubercles, surrounded by a hollow, and arranged in a direction more or less spiral, having internally a distinct woody axis, which communicates with the tubercles by woody processes. Leaves arising from the tubercles, succulent, entire, and veinless, except in the centre, where there is some trace of a mid-rib.

Five species in the coal formation.

One species in the oolite formation, viz.:—Mammillaria Desnoyersii, of Brongn. Ann. sc. 4, t. 19, f. 9, 10.

We subjoin a figure of *S. ficoides*, Lindley and Hutton, Pl. 34.

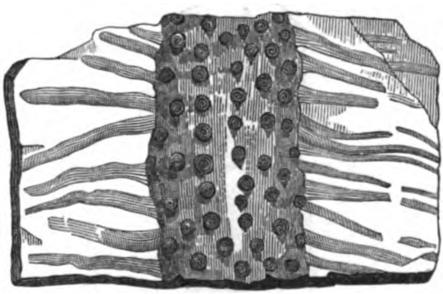


FIG. 159.

Class IV.—PHANEROGAMIC GYMNOSPERMS.

We shall here take occasion to remark, that having figured those genera which occur most commonly in the coal measures, and the chief depositaries of fossil

vegetation, we shall merely offer descriptions of most of the remaining plants, and, with one or two exceptions, refer for the plates and other details, to the works of Brongniart, Sternberg, and Lindley and Hutton.

9th Family.—CYCADEÆ.

LEAVES ONLY KNOWN.

Pterophyllum, from πτερον, a wing, and φυλλον, a leaf.

Leaves pinnated; leaflets almost equally broad each way, inserted by the whole of their base, truncated at the summit; veins fine, equal, simple, but little marked, all parallel.

Eight species in the lias and oolite.

We subjoin a figure of *P. comptum*, with magnified leaflet, Lindley and Hutton, Pl. 66.

FIG. 160.

Cycadites.

One species in the grey chalk.

Eight species in the oolite formation.

Nillsonia, from Professor Nillson.

Two species in the lias.

Zamia.

Fifteen species in the oolite and lias.

One species from a deposit unknown.

STEMS ONLY KNOWN.

Cycadeoidea, Buckland, Mantellia, Ad. Brongn.

The following dicotyledonous plants are of doubtful affinity :—Phyllotheca, annularia, bechera, asterophyllites, &c.

As this last genus is of frequent occurrence in the coal, we subjoin a figure and description of *asterophyllites foliosa*, Lindley and Hutton, Pl. 25.

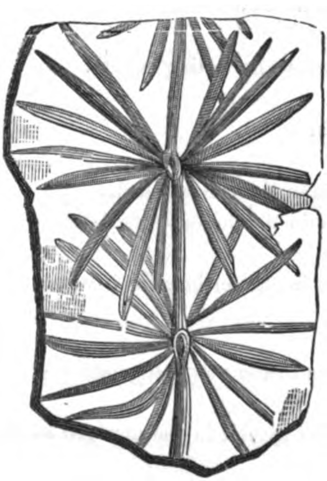


FIG. 161.

Asterophyllites. Bornia, Sternb.; Bruckmannia, Sternb.

Stem scarcely tumid at the articulations, branched; Leaves verticillate, linear, acute, with a single mid-rib, quite distinct at their base.

Twelve species in the coal formation.

One species in the transition beds.

This is considered to be an extremely heterogeneous assemblage, comprehending nearly all fossils with narrow, veinless, verticillate leaves, which are not united in a cup at their base.

10th Family.—Coniferæ, the Fir Tribe.

WOOD ONLY KNOWN.

Pinites.

Three species in the coal formation.

Peuce.

One species in the coal formation.

One species in the oolite.

Pinus.

Nine species in the tertiary strata.

Abies.

One species.

Taxites.

Five species in the tertiary beds.

One species in the oolite formations.

Podocarpus.

One species in the tertiary fresh-water formations of Aix.

Voltzia.

Four species in the new red sandstone.

Thuia.

Three or four species in the new red sandstone.

Thuytes.

Four species in the schistose oolite.

DOUBTFUL.

Brachyphyllum.

One species in the lower oolite formation.

Class V.—MONOCOTYLEDONOUS PHANEROGAMIÆ.

11th Family.—Fluviales.

Zosterites.

Four species in the lower green sand.

One species in the lias.

Two species in the upper fresh water formation.

Caulinites.

One species in the London clay.

12th Family.—The Palms.

STEMS ONLY KNOWN.

Palmacites.

One species in the lower beds of the London clay.

LEAVES ONLY KNOWN.

Flabellaria.

One species in the coal.

Three species in the tertiary formations.

Phœnicites.

One species in the tertiary formations.

Noeggerathia.

Two species in the coal measures.

Juniperites.

Three species in the tertiary beds.

Cupressites.

One species in the new red sandstone.

Zeugophyllum.

One species in the coal formation.

FRUIT ONLY KNOWN.

Cocos.
Three species in the tertiary formations.

13th Family.—Liliaceæ, the Lily Tribe.

Bucklandia.
One species in the Stonesfield slate.
Clathraria.
One species in the green sand.

LEAVES ONLY KNOWN.

Convallarites.
Two species in the variegated sandstone.

FLOWERS ONLY KNOWN.

Antholithes.
One species in the tertiary beds.

14th Family.—Canneæ.

Cannophyllites.
One species in a bed of coal.

Monocotyledonous plants of doubtful affinity.

STEMS ONLY KNOWN.

Endogenites.
Several species from the tertiary strata.
Culmites.
Three species from the tertiary beds.
Sternbergia. Columnaria of Sternberg.
Three species in the coal formation.

LEAVES ONLY KNOWN.

Poacites.
Several species in the coal formation.
Phyllites. Potamophyllites of Brongniart.
One species in the lower fresh water formation.

FRUITS ONLY KNOWN.

Trigonocarpum. Ad. Br.

Five species in the coal formation.

Amomocarpum. Ad. Br.

One species in the tertiary formations.

Musocarpum. Ad. Br.

Two species in the coal formation.

Pandanocarpum. Ad. Br.

One species in the tertiary strata.

CLASS VI. — DICOTYLEDONOUS PHANEROGAMIÆ.

15th Family.—AMENTACEÆ, THE BIRCH TRIBE.

Carpinus, betula, and comptonia.

One species of each in tertiary lignite.

DOUBTFUL AMENTACEÆ.

Salix, populus, castanea, and ulmus.

In upper fresh water formation.

16th Family.—JUGLANDEÆ, THE WALNUT-TREE TRIBE.

Three species in the tertiary strata.

One species in the upper beds of new red sandstone.

17th Family.—ACERINEÆ, THE SYCAMORE TRIBE.

Some dubious leaves found near Frankfort.

18th Family.—NYMPHACEÆ, THE WATER-LILY TRIBE.

Nymphæa.

Upper fresh water formations.

Flowering plants which cannot, with certainty, be referred to either the monocotyledonous or dicotyledonous class.

Æthophyllum, echinostachys, and palæoxyris.

One species of each in the new red sandstone.

Plants, the affinity of which has hitherto been regarded as uncertain, but which are now referred with great probability to the dicotyledonous division.

Sigillaria. Rhytidolepis, alveolaria, favularia, catenaria, &c., of Sternberg.

Stem conical, deeply furrowed, not jointed; scars placed between the furrows in rows, not arranged in a distinctly spiral manner, smooth, much narrower than the intervals which separate them.

About forty species in the coal formation.

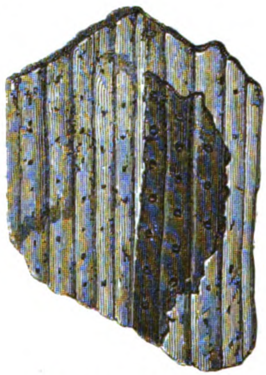


FIG. 162.—Sigillaria organum.

Volkmannia.

Stem striated, articulated; leaves collected in approximate, dense whorls. These are considered to be, probably, the leaves of *calamites.*

Carpolithes.

Under this name are arranged all the fossil fruits to which no other place is assigned.

ARRANGEMENT OF THE PLANTS OF THE COAL.—The most frequent and familiar of the coal plants may be classified under the following divisions:—First, ferns and *sigillariæ.* Secondly, *lepidodendra,* a doubt-

ful genus, provisionally referred to *lycopodiaceæ*; but, by the German botanist Corda, ascribed to *crassulaceæ*. Thirdly, *calamites*, allied to *equisetaceæ*. Fourthly, coniferous plants. Fifthly, *stigmariæ*, which appear to be an extinct family.

1. Ferns and Sigillariæ.—The leaves of flowerless plants differ from true leaves in many particulars, and are therefore called fronds. The genera of fossil ferns have been determined by the characters of these fronds, such as their mode of attachment to the *rachis* or stem, their shape, their method of branching, and the way in which the veins are distributed.

The student will find it necessary to devote peculiar attention to the fossil ferns, so as to be able to discriminate between the different genera and species, and to identify particular specimens. The four genera of familiar occurrence which most nearly resemble each other, and are therefore most difficult to distinguish, are *neuropteris*, *sphenopteris*, *pecopteris*, and *odontopteris*. The following, among others, may be mentioned as distinctive characters. *Neuropteris* is known from *sphenopteris* by its leaves being cordate at the base, while this character is reversed in *sphenopteris*, in which, near the base, the leaves are usually smallest; the shape of the leaflets is moreover different, those of *sphenopteris* being lobed, while those of *neuropteris* are not. *Pecopteris*, again, is distinguished from *neuropteris* by its leaves being occasionally tri-pinnate, which is never the case with *neuropteris*; the mid-rib of *pecopteris* also runs quite through the leaflet, while in *neuropteris* it vanishes at the apex; the veins, moreover, of *pecopteris* run almost perpendicular to the mid-rib; while in *neuropteris* they are oblique

and curved; and the genera *odontopteris* and *neuropteris*, are distinguished from each other by the veins of the former proceeding into the segments directly from their base, without collecting into a distinct mid-rib, and by those of the latter gradually diverging from the mid-rib, as they approach the point of the segments.

We subjoin, for the guidance of the learner, a magnified leaf of a familiar species of each genus here mentioned; and for farther particulars, such as the form, markings, and other characters of recent leaves and stems, analogous to those of fossil specimens, we again refer our readers to the splendid work of M. Brongniart, from which the following figures are taken.

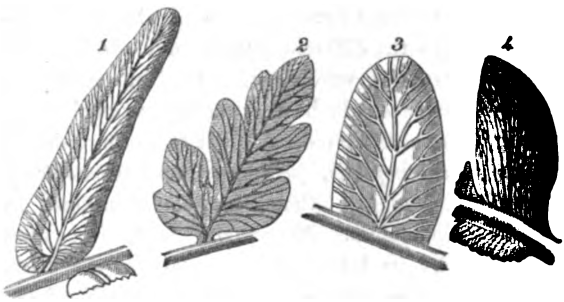


FIG. 163.—1. Neuropteris. 2. Sphenopteris. 3. Pecopteris. 4. Odontopteris.

SIGILLARIÆ.—The same deposits of the coal afford numerous fluted stems, or trunks of trees which, when they occur in the shale, are usually squeezed close and flat, by the pressure of the superincumbent strata, but when placed vertically or obliquely in the grit, or sandstone, are round and uncompressed. From presenting small impressions, occasioned by the decay and fall of the leaf-stalks, resembling markings made by a seal, they have obtained the name of *sigillariæ*. They

have also been figured and described by various writers on Fossil Botany, under the names of *rhytidolepis, alveolaria, favularia, catenaria*, &c. They have hitherto been considered as monocotyledonous plants; but later observers, particularly the late Mr. Bowman in a communication to the Geological Society, on the fossil trees, discovered on the Bolton Railway,* satisfactorily shows that the *sigillariæ* belonged to the dicotyledonous division. He founds this conclusion on the following evidence:—

The irregular, longitudinal and discontinuous, or anastomosing furrows on the surface of the stems; the swelling out of the stems at their base; their angle of dip, or downward direction of the roots; characters which he observes, are constantly observable in dicotyledonous, but never in monocotyledonous plants. He adduces marks of striæ as proving, with other evidence, that these trees have a separable bark, and finally, in slices of a tree of this kind, prepared for microscopic investigation, he discovered traces of medullary rays, which are universally recognised as indisputable proofs of dicotyledonous structure. The supposition that these plants were hollow, a circumstance which would be fatal to their dicotyledonous character, had previously been denied by Mr. Hawkshaw, who had stated that in tropical climates the interior of solid hard-wood trees is often consumed by insects, in an extremely short space, leaving the bark intact, and the tree apparently sound. Hence, it is inferred, that in the ultra-tropical climates of the carboniferous epoch, solid trees would be internally destroyed and rendered hollow in an excessively short period of time.

* See Proceedings, vol. 3, No. 63, p. 273.

While the *sigillariæ* are thus generally regarded as dicotyledonous, or exogenous trees, Dr. Lindley has divided from them another genus termed *caulopteris*, which he considers as true stems of tree-ferns. They are hollow, a circumstance which will be considered of little importance after the statements of Mr. Hawkshaw, quoted above; but the markings which they exhibit present so close a resemblance to those of existing tree-ferns, as to render their identity with those plants highly probable. They are, however, comparatively rare, while of *sigillaria*, forty species have been discovered in the coal, as well as a figure of the fossil stem, *caulopteris*, and of that of a familiar species of recent fern.

FIG. 164.—Caulopteris Phillipsii, Lindley and Hutton.

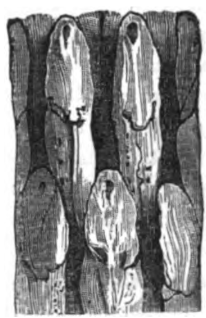


FIG. 165.—Stem of recent tree-fern.

II. Lepidodendra.—These are a very numerous class of fossils from the same deposits of the coal. They have hitherto been conceived to be referable to the family of club-mosses, and the larger species were regarded as forming a transition to the coniferous plants.

The living varieties of their supposed analogues abound in tropical climates, they generally creep on the ground,

FIG. 166.

some grow erect, but none exceed three feet in height; whereas fossil specimens have been found some thirty feet high, while fragments have been discovered indicating a much larger size.

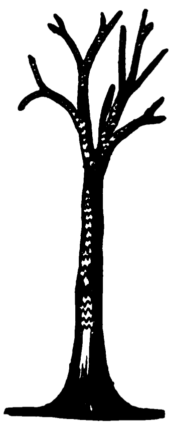


FIG. 167.—Branching Trunk of L. Sternbergill Foss. Flo. 203.

FIG. 168.—Branching Stem, with bark and leaves, *Flora der Vorwelt, Erstes Heft*, Leipzig, 1820. Pl. II.

Professor Corda, however, the continuator of the researches and the writings of Count Sternberg, and curator of the Bohemian National Museum at Prague, in his work above mentioned, *Skizzen der vergleichenden Phytotomie vor-und jetztweltlicher Pflanzen-Stämme*, which may be rendered, Sketches of the Analogies of Structure in the Stems of recent and fossil Plants, p. lxxi., refers them to a totally different family. He declares that both in general habit, and external and internal structure, they are far more closely allied to the existing *crassulaceæ* than to any other tribe, and that both in external and internal characters they are strongly distinguished from *lycopodiaceæ*. With regard to the *lepidostrobi*, he observes that they have never yet been proved to be the fruit of *lepidodendron*; and he considers them the male flowers (*die männlichen Blüthen*) of a plant of the fir tribe. Mr. Hawkshaw, as we have already stated, found them at the base of trees, considered by the late Mr. Bowman to be *sigillariæ*.*

The *crassulaceæ*, or house-leek family, are described by Dr. Lindley as an order of plants comprising 272 species, of which 133 are found at the Cape of Good Hope, 52 in Europe, and the remainder in various regions, chiefly those of the temperate zone. They occur in the driest situations, where not a blade of grass nor a particle of moss can grow, on naked rocks, old walls, or sandy hot plains, alternately exposed to the heaviest dews of night, and the fiercest rays of the noon-day sun. Soil is to them a something to keep them stationary, rather than a source of nutriment, which in these plants is conveyed by myriads of

* See page 328.

mouths, (invisible to the naked eye, but covering all their surface,)—to the juicy beds of cellular tissue which lie beneath them. The following is a figure of a typical species of this family.

FIG. 169.—Crassula tetragona, from De Candolle's *Plantes Grasses.*

III. Calamites.—These have already been described as allied to the *equisetaceæ*, or horse-tail tribe; but they differ in their much larger size, the analogous plants in these regions being only two feet high, while a gigantic species of the tropics is no more than five feet in height, and an inch in diameter; whereas their fossil representatives far exceed these dimensions, both in circumference and elevation; they were farther distinguished by having a thin bark, and are now generally considered a separate and extinct family.

IV. The Coniferæ.—It has been remarked, as a striking circumstance, that the fossil trees of the coal

of this character bear a close resemblance to those of the existing genus *araucaria*, or pine of Norfolk Island; slices of the wood, when inspected by the microscope, showing that the ducts or glands peculiar to this order of plants are arranged in a similar manner, that is, alternately in double and triple rows.

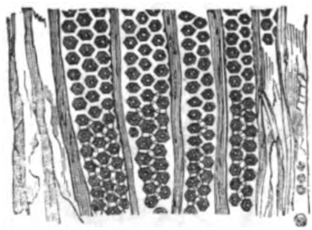


FIG. 170.

V. STIGMARIÆ.—These have recently been most fully and ably discussed, in a valuable contribution to the Geological Society,* by Mr. Logan. As the paper will be again cited, in treating of the coal formations, we shall content ourselves for the present by remarking, that Mr. Logan adopts the idea of Mr. Steinhauer, that the *stigmaria* was a large, succulent water-plant, the stem, in its compressed fossil state, varying from two to six inches in diameter, and having numerous processes,† which proceed vertically, horizontally, and obliquely, and traverse the beds in every direction. These processes Mr. Logan has traced to a distance of eight or ten feet from the stem; and he is of opinion they have had a horizontal range of twenty feet. From the number of these plants, Mr. Logan

* See Proceedings, vol. 3, No. 69, p. 275.

† See fig. 133.

concludes that they have furnished the material for the great mass of our beds of coal, and from their constant presence in every seam of coal over the whole area of South Wales, he derives evidence of the most conclusive character, as to the coal having been formed by submergence on the spot, and not by drift as heretofore supposed.

For more complete details, explanations of technical terms, &c., the student is referred to the elementary works on botany already mentioned. As the leaves, however, constitute a highly important feature in this department of science, we shall here introduce a few remarks descriptive of their characters, as they occur most commonly in fossil plants.

Leaves are either *simple*, that is, consisting of one leaf, as in the lily; or *compound*, composed of several leaflets, as in the rose. *Compound* leaves are distinguished into *pinnate*, *bipinnate* and *tripinnate;* and into *ternate*, *biternate*, and *triternate*, &c.

A *pinnate*, (or winged) leaf, is one, the stem or footstalk of which has several leaflets at each side, growing, at equal distances, in pairs.

FIG. 171.

A *bipinnate* leaf is one in which the footstalk itself is divided, and branches out into other footstalks, each of which supports leaflets, corresponding in all their modifications to those of the simply pinnate leaf.

FIG. 172.

A *tripinnate* leaf is of the same description as the above, once more decompounded; the footstalk being *bipinnate*, and supporting leaflets, as in the former modes.

FIG. 173.

The term *ternate*, with its compounds, indicates an

analogous arrangement. A *ternate* leaf is so called when the footstalk supports three leaflets;

FIG. 174.

a *biternate* leaf is when the common footstalk supports three others, each of which supports three leaflets;

FIG. 175.

and a *triternate* leaf is only a farther decomposition of the above.

FIG. 176.

A *pinnatifid* leaf is one which is cut transversely into several oblong, parallel segments;

FIG. 177.

and *bipinnatifid* denotes another decomposition of the same form.

FIG. 178.

As to position, leaves are either *radical*, that is, proceeding from the crown, or radical plate; or they are *caulinar*, borne on the stem; and either *sessile* or *petiolate*, that is, either sitting or having footstalks. Sessile leaves are sometimes *vaginant*, that is, sheathing, as in grasses; or *amplexicaule*, stem-clasping, as in many umbelliferous plants; or *connate*, situate opposite each other, and united at the base, circumscribing the stem, as in the leaves of the honey-suckle, or they are *decurrent*, running down the stem, &c. &c.

As regards shape, their modifications are innumerable;

the chief of these, as regards fossil plants, may be stated as follows:—They are *linear*, narrow, and long, with parallel sides, and of equal breadth throughout; or *lanceolate*, of a narrow, oblong form, tapering towards each end; *verticillate*, growing in rings or whorls; they are farther, *ovate*, egg-shaped; *obovate*, the same form with the large end upwards; *cordate*, heart-shaped, *obcordate* the heart-shape reversed; *hastate*, spear-shaped; *auricled*, having appendages like ears; *lobed*, that is with the margins of their segments rounded, while according to the number of lobes, the leaf is termed *bilobate*, *trilobate*, &c.; they are *adherent* or not *adherent* to the stem, or to each other; they are *deciduous*, or withering and falling; or *persistent*, the reverse of this, remaining; they are *flabelliform*, or fan-shaped; or *imbricated*, placed one over another, like the tiles of a house. They are also *succulent*, soft and juicy; *coriaceous*, resembling leather, &c., &c.; the *areolæ* are the spaces from which the leaves have fallen.

Venation constitutes a highly important character in fossil botany, since the veins often afford very conclusive evidence as to the generic character of a plant. The *costa* is the mid-rib from which the smaller veins usually proceed; these are *simple*, (that is, undivided,) or *dichotomous*, (forked,) once, or more than once; *anastomosing* (running into each other;) *reticulated*, forming a net-work; or *radiating*, proceeding from a centre, like the spokes of a wheel, &c., &c. See Dr. Lindley, Sir J. E. Smith, Sir W. Hooker, &c., &c.

EXERCISES

ON FOSSIL BOTANY.

1. Describe the arrangement of plants according to the mode of Jussieu, or the natural system, as it is termed.

2. Explain the term, cotyledon.

3. Describe the monocotyledonous and dicotyledonous divisions of plants.

4. Show the difference of the two classes, as developed in the seed, the wood and the leaf.

5. Describe the successive epochs in the botany of the ancient earth, as proposed by Brongniart, and modified by Sternberg.

6. Name the six divisions of the vegetable kingdom adopted by Brongniart.

7. Copy and commit to memory the eighteen families which form the six divisions above stated.

8. State the experiment of Dr. Lindley, as to the power of certain plants to resist decomposition in water, and its results, with the remarks of Count Sternberg.

9. Describe the nature of the flora of the ancient earth, and the peculiar climate indicated by such a character of vegetation.

10. State the period when this flora gradually assumed its present European character.

11. Commit to writing a list of the genera of fossil plants, with the derivation of their respective names.

12. Copy, on tracing paper, a typical specimen of each genus.

13. Seek, as usual, to combine practice with theory,

and identify the real specimens of each genus, with their description in books.

14. Name the genera which most closely resemble each other, and state the characters which distinguish *odontopteris* from *pecopteris*, and the latter from *neuropteris*, and *sphenopteris*.

15. Trace the leaves (with their venations) figured in page 338.

16. Trace in like manner a pinnate, bipinnate and tripinnate; and a ternate, biternate, and triternate leaf.

17. Trace from the work of Brongniart, the leaves (with their venation) of recent ferns resembling the fossil species.

18. State the distinction between *caulopteris*, and *sigillaria*, and the reasons for establishing the former as a separate genus.

CHAPTER IX.

PALÆONTOLOGY.

COLLECTIONS:—ROYAL COLLEGE OF SURGEONS, BRITISH MUSEUM, GEOLOGICAL SOCIETY.

AUTHORS:—CUVIER, OWEN, MANTELL, ROGET, BUCKLAND, &C.

ARRANGEMENT of the animal kingdom, abridged from Cuvier.*

I. VERTEBRATA.

Mammalia.

Bimana,	Man.
Quadrumana,	Monkey, Ape, Lemur.
Cheiroptera,	Bat, Colugo.
Insectivora,	Hedge-Hog, Shrew, Mole.
Plantigrada,	Bear, Badger, and Glutton.
Digitigrada	Dog, Lion, Cat, Martin, Weasel, Otter,
Amphibia,	Seal, Walrus.
Marsupialia,	Oppossum, Kangaroo, Wombat.
Rodentia,	Beaver, Rat, Squirrel, Porcupine, Hare.
Edentata,	Sloth, Armadillo, Ant-eater, Pangolin Ornithorhyncus.
Pachydermata,	Elephant, Hog, Tapir, Rhinoceros, Horse.

* From the admirable Bridgewater Treatise of Dr. Roget.

Ruminantia,	Camel, Musk-Deer, Giraffe, Antelope, Goat, Sheep, Ox.
Cetacea,	Dolphin, Whale.

AVES, BIRDS.

Accipitres,	Vulture, Eagle, Owl.
Passeres,	Thrush, Swallow, Lark, Crow, Sparrow, Wren.
Scansores,	Woodpecker, Cuckoo, Toucan, Parrot.
Gallinæ,	Peacock, Pheasant, Grouse, Pigeon.
Grallæ,	Plover, Stork, Snipe, Ibis, Flamingo.
Palmipedes,	Auk, Grebe, Gull, Pelican, Swan, Duck.

REPTILIA, REPTILES.

Chelonia,	Tortoise, Turtle, Emys.
Sauria,	Crocodile, Lizard, Gecko, Chameleon.
Ophidia,	Serpents, Boa, Viper.
Batrachia,	Frog, Salamander, Newt, Proteus, Siren.

PISCES, FISHES.

Acanthopterygii,	Perch, Mackarel, Sword-fish, Mullet.
Malacopterygii	Salmon, Herring, Pike, Carp, Silurus, Cod, Sole, Remora, Eel.
Lophiobranchi,	Pike-fish, Pegasus.
Plectognathi,	Sun-fish, Trunk-fish.
Chondropterygii,	Lamprey, Shark, Ray, Sturgeon.

II. MOLLUSCA.

1. Cephalopoda,	Cuttle-fish, Calamary, Nautilus.
2. Pteropoda,	Clio, Hyalæa.
3. Gasteropoda,	Slug, Snail, Limpet, Whelk.
4. Acephala,	Oyster, Mussel, Ascidia.
5. Brachiopoda,	Lingula, Terebratula.
6. Cirrhopoda,	Barnacle.

III. ARTICULATA.

1. Annelida.

Tubicola,	Serpula, Sabella, Amphitrite.
Dorsibranchia,	Nereis, Aphrodite, Lob-worm.
Abranchia,	Earth-worm, Leech, Nais, Hair-worm.

2. Crustacea.

1. Malacostraca,	
Decapoda,	Crab, Lobster, Prawn.
Stomapoda,	Squill, Phyllosoma.
Amphipoda,	Gammarus, Sand-hopper.
Læmodipoda,	Cyamus.
Isopoda,	Wood-louse.
2. Entomostraca,	Monoculus.

3. Arachnida.

Pulmonalia,	Spider, Tarantula, Scorpion.
Trachealia,	Phalangium, Mite.

4. Insecta.

Aptera,	Centipede.
Coleoptera,	Beetle, Glow-worm.
Orthoptera,	Grasshopper, Locust.
Hemiptera,	Fire-fly, Aphis.
Neuroptera,	Dragon-fly, Ephemeron.
Hymenoptera,	Bee, Wasp, Ant.
Lepidoptera,	Butterfly, Moth.
Rhipiptera,	Xenos, Stylops.
Diptera,	Gnat, House-fly.

IV. ZOOPHYTA.

1. Echinodermata,	Star-fish, Urchin.
2. Entozoa,	Fluke, Hydatid, Tape-worm.

3. Acalephæ,	Actinia, Medusa.
4. Polypi,	Hydra, Coral, Madrepore, Pennatula.
5. Infusoria,	Brachionus, Vibrio, Proteus, Monas.

EXTENT OF THE SUBJECT.—The studies which pass under the term palæontology, comprising animal physiology, comparative anatomy, and a general knowledge of the laws of structure, are so important and extensive, as to render it obviously impossible to describe them, at length, within the brief limits of an introductory work; while the proficiency which enables the skilful comparative anatomist not only to refer the single bone to the peculiar animal of which it has formed a part; but in many instances of extinct types of being, to reconstruct the entire form anew, must be the result of talent, time, and opportunity, such as can fall only to the lot of few.

Yet, though a comprehensive detail is beyond the limits of any mere introduction, it may still be possible to furnish information which may prove useful and instructive; and though a perfect proficiency in acquirements so varied and extensive, must be confined to a limited number of individuals, a general acquaintance with these subjects is attainable by all. The arrangement of the animal kingdom, abridged from Cuvier, prefixed to the present chapter, will furnish an idea of the classification of animals; and of these, the reader is already aware, that those appertaining to the class mammalia, (such as give suck to their young,) occur only in deposits of the tertiary order, (those which lie above the chalk;) while the animal forms discovered in the secondary rocks, with one or two solitary exceptions, (that of the *didelphys*, of Stones-

field, and its associate, which will be noticed hereafter) are all of the reptilian type. Though, we repeat, a knowledge of osteology, and a general acquaintance with structure are not attainable, nor, in fact, required by the beginner in geology, yet there is one portion of the animal frame, the characters of which are usually so clear and well-defined as to render it a comparatively easy task to recognise them, and to determine the class, order, and genus of animal to which they belong—we allude, of course, to the teeth. Since the providing a due supply of food is necessarily an object of the first importance to the support of animal life, the instruments by which this food is to be masticated and prepared for digestion, appear, in every instance, to have been the peculiar objects of creative power and wisdom, and are invariably found to exhibit a structure admirably adapted to the habits of the creature of whom they form so important a part.

ARRANGEMENT OF THE TEETH.—Their arrangement in the jaws of those animals which possess the most complete dentition, is as follows. The front teeth have a sharp-edged, or chisel-shape, like the blades of a cutting instrument, and hence they are denominated *incisors*. The conical teeth, immediately following the incisors, are called *cuspidate*, or *canine* teeth, because they are particularly conspicuous in dogs. In the larger carnivora, as the lion and the tiger, they constitute most powerful weapons of destruction, and in the boar they form the tusks of the animal. All the teeth which are placed farther back in the jaw are termed *molar* teeth, or grinders, but the term comprises teeth of several different forms. Those which are placed next to the canine

teeth partake of the conical form, and have pointed eminences, these are called the *false molar* teeth, and also, from their having generally two points or cusps, the *bicuspidate* teeth. The posterior molar teeth are differently shaped in different animals. In the carnivora, they are raised into sharp, and often serrated ridges, having many of the properties of cutting teeth; in insectivorous and frugivorous animals, their surface presents prominent tubercles, either pointed or rounded, for pounding their food; while in quadrupeds that feed on grass or grain, they are flat and rough, for the purpose simply of grinding.

Teeth of the Carnivora.—A striking difference is also presented in the carnivorous and herbivorous tribes, not only as regards the form and character of the teeth, but also the structure of the jaws by which they are set in motion; in the former, of which the tiger may serve as the type,

FIG. 179.—Skull of a Tiger.

we perceive the incisors, or cutting teeth, in front; the canine, or sharp fangs, at the side; and molar, or bruising, or crushing teeth, in the back part. The molar are armed with pointed eminences, which correspond with those of the lower jaw, so as to interlock exactly with them, like wheelwork, when the mouth

is closed; the whole of the teeth being sharp and cutting, and covered with enamel. The spaces for the insertion of those muscles which give motion to the jaw are large and prominent, and the articulation of the jaw with the skull constitutes a hinge-joint, causing the jaws to close flat, like the lid of a box, but not admitting any rotatory or grinding motion. In other words, we have an apparatus admirably adapted for tearing, or cutting flesh, or for cracking, or crushing bones; but by no means suited for grinding, or reducing to a pulp, the stems or other portions of vegetable substance.

OF THE HERBIVORA.—In herbivorous animals, on the contrary, of which the horse may be cited as an example,

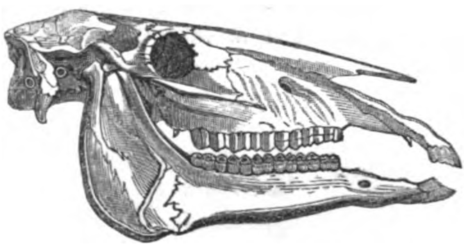


FIG. 180.—Skull of the Horse.

the sharp fangs of the teeth are wanting, the surfaces of the molar teeth, instead of rising into eminences, are flattened and spread out to a considerable extent; and in place of being wholly covered by enamel, that substance is arranged into deep vertical layers, alternating with bony matter, so as to form a rough and grinding surface. Again, the jaws are loosely articulated with the skull, so as to allow of lateral motion, and the

muscles, placed internally between the sides of the jaw and the basis of the skull, which effect that motion, are thick and strong, so as to afford every facility for that rotatory movement, which is perfectly adapted for a grinding process. In short, in the peculiar structure of the teeth, and of the machinery by which their movement is produced, we have an apparatus perfectly calculated to grind, and reduce to a pulp, those vegetable substances on which the creature is ordained to feed, but as perfectly unfitted for tearing or cutting the fleshy fibres of animal food.

Of the Rodentia.—The rodents, or gnawers, of whom the squirrel may offer a representation,

FIG. 181.—Skull of a Squirrel.

constitute a family of mammalia, whose dental characters differ, in a marked manner, both from those of the herbivorous and carnivorous tribes. They are all animals of diminutive stature, whose teeth are expressly formed for gnawing, nibbling, and wearing away, by continued attrition, the harder textures of organized bodies. They have two incisors, or front teeth, in each jaw, which are long, sharp, and cutting, having the exact form and action of a chisel; they lock together so closely as to render a grinding movement impossible; a new adjustment has, therefore, been supplied, and the articulating surface of the jaw is elongated, so as to allow of the jaw being freely moved backwards and forwards, like the motion of a carpenter using his

plane. These incisors, moreover, are guarded by a plate of enamel only on their anterior convex surfaces, so that by the wearing down of the ivory behind this plate, a wedge-like form, of which the enamel constitutes the fine-cutting edge, is speedily given to the tooth, and is constantly retained. The incisors being implements of constant use, are renewed by perpetual growth, and there is a special provision for their support in a bent socket. The molar teeth have surfaces irregularly marked with raised zig-zag lines, rendering them perfect instruments of trituration.

TYPE OF THE CARNIVORA.—The student has only to select a type of the various orders, in order to exemplify not only the dental apparatus and mode of subsistence, but also the habits, and, it may be said, the moral characteristics of each distinct tribe. To commence, for instance, with the carnivora; we have only to direct our attention to so common and familiar an object as the cat, to recognise the exemplification of all the characters which we have described above. The teeth are sharp, and covered with enamel; the jaws have a hinge-like joint, and close flat, like a pair of shears, so as to cut all that comes between them. Pursuing the inquiry, we find that the other parts of the animal frame are in unison with its dental structure: for instance, that the vertebræ of the neck have sufficient power not only to bear off the little mouse, its prey, but even the more delicate burden of its own young. Its fore-feet are armed with claws fitted to seize and tear the flesh of its victim, while its hind-limbs are endowed with swiftness to pursue and overtake its object. And ascending from the mere mechanical structure to the instincts and propensities of the animal, we find these to be perfectly

accordant with its physical frame. We observe that it is cunning and artful, and prone to hide itself and lay wait for its victim; it is, moreover, cruel and ferocious, or it would spare the prey on which it is destined to subsist.

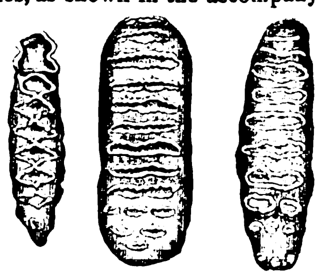
Of the Herbivora.—If, on the other hand, we direct our attention to the herbivora, and select, as an equally familiar instance, the ox, we remark a striking contrast, both as regards the physical structure and moral instincts and qualities of the animal. The teeth, instead of being sharp and cutting, are flat and broad; and, in place of being covered with enamel, are composed of vertical layers of that substance, alternating with deposits of bony matter, so as to produce that rough and grinding surface which we have before mentioned, as best adapted for the trituration of vegetable matter. The jaw articulates with the skull, so as to allow of that rotatory, grinding motion already described, as best calculated to give efficiency to such a dental apparatus, for the purpose of reducing to a digestible state the vegetable substances which form the food of the animal, and thus promoting its health and well-being. Again, we perceive that the fore-feet, instead of being armed with claws, terminate in a hoof, while we observe no peculiar swiftness, or power of leaping, in the hinder limb, for the purposes of pursuit; no especial cunning or instinct, for entrapping, or catching its prey; no provision for strength in the vertebræ of the neck for carrying it off; no cruelty or ferocity; but its physical structure and its moral instincts and propensities are found to be in perfect harmony with each other.

Of the Rodentia.—Or, if we devote the same attention to the rodentia, we find the teeth to be of the structure previously detailed; the incisors sharp, cut-

ting, and shaped like a chisel, while the mechanism of the jaw is such as to allow the motion, backward and forward, already pointed out, and we have but to watch a rabbit, while eating and nibbling its food, to observe all the peculiarities already described.

The laws of nature, as the student is, of course, already aware, though plain and simple, are prevalent and extensive, and we have only to extend our views to the tropical climate and productions of the ancient earth; in short, to transform our cats into tigers and hyenas; and our oxen into elephants and mastodons; to realize the structures and habits of the carnivorous and herbivorous tribes of the primeval time.

In the larger herbivorous animals, whose teeth are of more complete structure, we discover, in addition to the enamel and the ivory, a third material, which unites the vertical plates of those substances, and performs the office of an external cement. It-bears the name of *crusta petrosa*, and resembles ivory in its texture, and its extreme hardness, but is usually more opaque and yellow than that object. The three substances are exhibited in the teeth of the elephant, but they are differently disposed, both in the two existing and the extinct species, as shown in the accompanying figures.



a b c

FIG. 182.—Teeth of Elephants.

In the African species, *a*, the enamel forms a series of lozenge-shaped lines. In the Asiatic variety, *b*, it constitutes a succession of narrow transverse bands, having the ivory in each case on their interior, and the *crusta petrosa* on their outer side, which latter substance also composes the whole circumference of the section. It will thus be seen, that the teeth of the extinct elephant, *c*, bore a much greater resemblance to those of the Asiatic than of the African variety.

We subjoin a figure, representing the skeleton of the celebrated elephant from the ice, which was discovered in the banks of a river in Siberia, in which it had been frozen up for ages. The animal was found with its flesh, even to the ear and capsule of the eye itself, in a fresh and perfect state; the skeleton, which is placed in the museum at St. Petersburg, is fifteen feet long, and nine feet high.

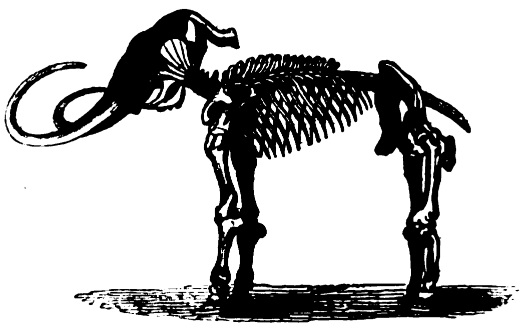


FIG. 183.—Elephas primigenius.

THE MASTODON.—The name of the mastodon, which is compounded of two Greek words, signifying mammillary

teeth, is derived from the structure of the tooth, which is composed of ivory and enamel only; the enamel, which is extremely thick, is spread over the crown of the tooth, which, when yet unworn, is divided into two transverse elevations, or processes, which are again subdivided into two obtuse points. The creature had, however, no relation to the carnivora, for the teeth, though covered with enamel, are destitute of the serrated, cutting edge; in the worn teeth, the protuberances have, evidently, been reduced by the action of grinding to the lozenge-shaped appearances which they now present, and the skull and jaws alike offer characters which identify the animal with the herbivorous tribes. There are numerous species, differing materially in size and other characters, and the great mastodon, the largest known variety, is considered to have differed from the elephant, merely in being longer and thicker, and in the different character of its teeth; but to have resembled it in possessing a trunk or proboscis, tusks, and four molar teeth in each jaw, but no incisors. From the structure of the teeth, which are more powerful than those of the elephant, it is conceived that while the elephant is known to feed on the softer kinds of vegetable substances, the mastodon could tear up shrubs, and grind even their stems and roots to pulp, by the action of its powerful jaws, and enormous teeth. We have already alluded to the fact, that the casual resemblance of the teeth to those of the human subject, has given rise to the fable which prevails in the mythology of all ancient nations, of the existence of certain giants, who warred against the gods, and being overcome by their celestial

opponents, were crushed, and buried by them beneath the rocks.

The British Museum contains a splendid series of teeth, together with several magnificent skulls, chiefly from the Himalayeh mountains of Hindostan; Ohio; other districts of the United States, and various parts of the continent of Europe.

THE MISSOURIUM, OR TETRACAULODON.—A specimen having recently been exhibited at the Egyptian Hall, Piccadilly, under the above names, together with a collection of mastodontoid remains collected by Mr. Koch, chiefly in the state of Missouri, North America, Professor Owen read a memoir descriptive of its character at the meeting of the Geological Society, February 23, 1842, the substance of which may be stated as follows:—After observing that the specimen was one of the finest ever discovered, and worthy the place of honour in any national museum, he proceeded to describe its structure and to ascertain its real position in the animal kingdom. He remarked that the bones, from the want of a correct knowledge of its osteology, were placed in an unnatural state of collocation; from which circumstance, both its height and length were greatly exaggerated, and he stated its correct dimensions to be about ten feet in height, and about sixteen in length. The two tusks of the upper jaw, which are placed extending in a horizontal direction, he described as occupying an undue position, and observed that they ought unquestionably to be curved upwards; the fact that one of them was found presenting the horizontal posture being of no importance, since the mode of insertion is such as to allow the tusk to rotate in any direction. Addressing his attention next to the generic appellation, *tetracaulodon*, he denied the existence of

such a genus, as established by an American *savant*, Dr. Godman, and described the facts to be as follows:—The young mastodon, he stated, possessed four tusks, two in the upper, and two in the lower jaw. The two in the upper jaw remained through life, in both sexes, but in the female, the two in the lower jaw both decayed and fell out, as the animal grew up, the sockets becoming obliterated altogether; while in the male, the left one only perished, and the right remained; a circumstance, he added, which ought to have suggested the name *tricaulodon*, rather than *tetracaulodon*, as better descriptive of the supposed new genus. In conclusion, from its osteological structure and general characters he had no hesitation in declaring it to be no new animal, but a very fine specimen of a species of mastodon, already known, and described and figured by Cuvier, as the *mastodon giganteum*. On the other hand, Dr. Grant, in a memoir, read before the Geological Society, June 1st of the same year, maintains a contrary opinion, and contends for the correctness of the genus *tetracaulodon* established by Dr. Godman, founding his conclusions chiefly on the dental characters of the specimen as contrasted with those of the mastodon. He considers that the teeth were of greater length, and consequently, that the jaw was more elongated; while the tusks and their *alveoli* presented characters, in his opinion sufficiently distinctive, to establish the legitimacy of the new genus.

As the skeleton, together with the entire collection formed by its indefatigable collector, Mr. Koch, has been purchased by the Trustees of the British Museum, and is about to be exhibited in the fossil department of that establishment, it will be rendered more accessible to

examination, and its true character will doubtless speedily be ascertained. The accompanying wood engraving depicts the animal as exhibited,

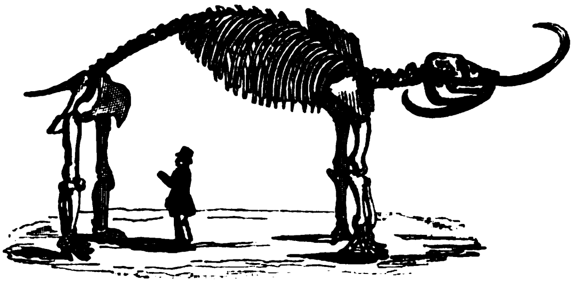


FIG. 184.—The Missourium.

while the following figure displays the appearance it would present, if deprived of its tusks, and appearing as the *mastodon giganteum.*

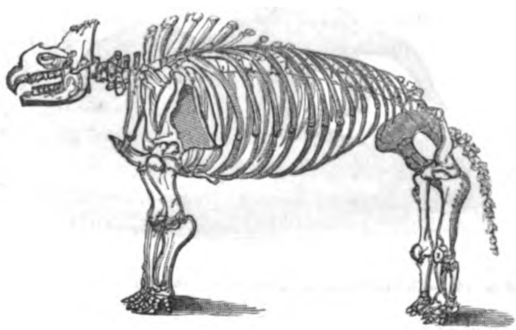


FIG. 185.—The Mastodon giganteum.

THE DEINOTHERIUM.—This, which is formed of two Greek words, meaning a terrible wild beast, is the injudicious and unphilosophical appellation bestowed on

an animal whose teeth resemble those of the tapir. It is conceived to have been related to the hippopotamus, and to have constituted a connecting link between the *pachydermata*, and the *cetacea*. Its most striking peculiarity consists in the existence of two enormous tusks, which are fixed in the lower jaw in a downward direction, as those of the walrus are in the upper. It is conceived that the creature had a proboscis, or trunk. A difference of opinion has prevailed with regard to the tusks, and while some naturalists have conceived that they were intended for digging the ground, and rooting up the vegetables on which the animal fed; others, with more probability, contend, from their unworn state, that they were never used for the purpose of disturbing the soil, but, like those of the elephant, were intended solely for defence.

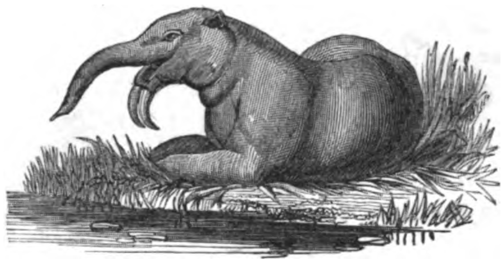


FIG. 186.—The Deinotherium, restored; from Dr. Buckland's Bridgewater Treatise.

THE MEGATHERIUM.—This is another unmeaning name which, signifying only a great wild beast, is bestowed on a colossal creature of the sloth tribe, whose remains have as yet been discovered only in South America. For more ample details, the student is re-

ferred to Dr. Buckland's Bridgewater Treatise; it may be sufficient here to state that the creature was about nine feet long, and seven feet high, while its bulk was colossal, the thigh bone being three times the circumference of that of the elephant, and the pelvis twice the breadth. It had no incisor teeth, and the molars, which are seven inches long, are prismatic in form, composed, like those of the elephant, of ivory enamel, and *crusta petrosa*, and are so shaped as always to present two cutting, wedge-shaped, salient angles, a structure peculiarly adapted for cutting and triturating vegetable substances. A skeleton of the animal exists at Madrid; a considerable portion of its osteology discovered in South America, by Sir Woodbine Parish, is placed in the College of Surgeons; and a model of these last remains is exhibited in the British Museum.

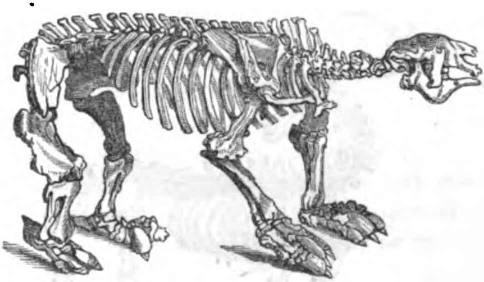


FIG. 187.—The Megatherium.

The *megatherium* was formerly conceived to have possessed a coat of bony armour, but Professor Owen has satisfactorily shown that the cuirass or covering could not have belonged to this animal, but that it appertained to one of a smaller size, a kind of large

armadillo, to which, from the fluted or sculptured character of its teeth, he has given the name of *glyptodon*.*

THE MEGALONYX, (or great-clawed animal, as its name imports,) has been discovered in North America. It is of analogous structure and character to the *megatherium*—both are referred to the sloth tribes, and are considered to be intermediate between the sloths, armadillos, and ant-eaters.

THE MEGACEROS, OR FOSSIL ELK OF IRELAND.—We subjoin a figure of this animal, whose remains are largely found in the sister kingdom, and have also been discovered in various parts of England. An entire skeleton recently discovered in the vicinity of Limerick has been purchased by the Trustees of the British Museum, and is now about to be exhibited in the fossil department of that establishment.

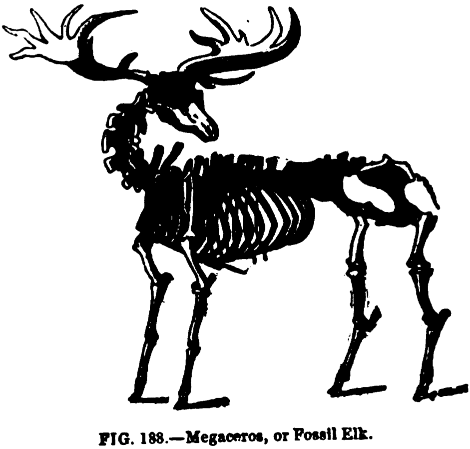


FIG. 188.—Megaceros, or Fossil Elk.

* See Trans. Geol. Soc. vol. vi. p. 81.

As the latest addition to our stores of palæontological knowledge, we would mention that Professor Owen has recently received from New Zealand, the bones of a colossal bird allied to the ostrich, which he considers to have been eleven feet in height. These remains were discovered in the alluvial deposits of that country. The professor assigns the provisional name of *deinornis* to this gigantic individual of the feathered tribes.

FOSSILIFEROUS CAVERNS. — The most celebated instances of these on the Continent, are the Caves of Gaylenreuth, and Forster's Höhle, in Bavaria, together with similar caverns in the South of France, North America, Australia, and various other localities. In this country the Cave of Kirkdale, in Yorkshire, and Kent's Cave, near Torquay, Devon, are the most celebrated. In general they contain the bones and teeth of bears, tigers, hyenas, and other carnivora; and of elephants, mastodons, and various herbivora on which they preyed; the organic remains being usually embedded in a deposit of stalagmite which forms the flooring of the cave. The Cave of Kirkdale is considered by Dr. Buckland to have been, in a peculiar degree, the resort of hyenas, not only from the quantity of their bones, and other exuviæ there discovered, but from the remains of the herbivorous tribes occurring with them, as the elephant, mastodon, ox, horse, &c., &c., it being the habit of that animal in those countries of which it now is a native, to feed on the bodies of dead animals, which it drags into caves and recesses to devour. For more ample details, the reader is referred to the work of M. Marcel de Serres, on Caverns, and to Dr. Buckland's Reliquiæ Diluvianæ.

We subjoin figures of the teeth of several of the mammalia, for the guidance of the student.

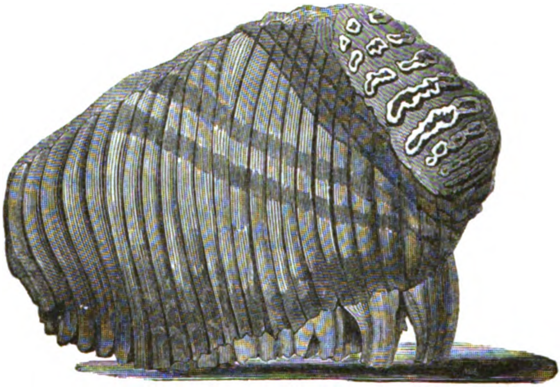


FIG. 189.—Elephas primigenius, or mammoth, from Brighton Cliffs. Molar of lower jaw, right side, one third of natural size.

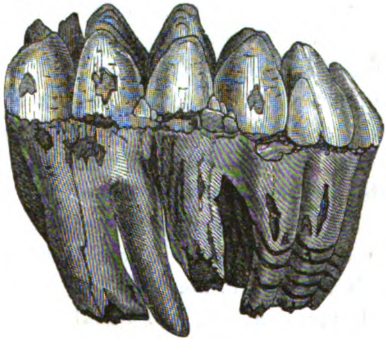


FIG. 190.—Mastodon ohioticus. Molar tooth, one-fourth of natural size. Collection of the author.

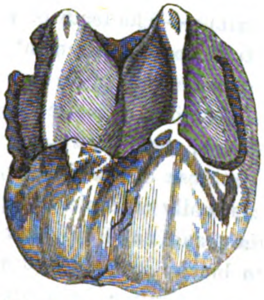


FIG. 191.—Deinotherium, Cuvier.

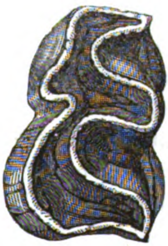


FIG. 192.—Rhinoceros, from fresh-water tertiary strata; molar, lower jaw. Collection of British Museum.

FIG. 193.—Hippopotamus, molar, lower jaw. Collection of British Museum.

FIG. 194.—Recent Elk, grinding surface of molar, upper jaw.

FIG. 195.—Horse, from Brighton Cliffs, second molar, lower jaw. Author's Collection.

Teeth of Reptiles.—The teeth of reptiles present a different structure and arrangement from those of mammalia. As several of them do not masticate their food, but gorge it entire, as is the case, in fact, with all the serpent tribes, their teeth are less expressly formed for the purpose of mastication, but are slight and small in size, usually of conical shape, and marked with vertical striæ; and as, from their fragile nature, they are liable to break, or to be worn out, provision is made for their substitution, by a succession of fresh teeth, formed within the old. Thus, in the crocodile, which may be assumed as the type, the teeth are sharp-pointed, hollow cones, composed of ivory and enamel, and are renewed by the new tooth being formed in the cavity of that which is to be replaced. As the new tooth, *a*, increases in size, it presses against the base of the old one, *b*, and, entering its cavity, acquires the same conical form: so that when the old tooth is shed, the new one is ready to supply its place.

FIG. 196.—*a*, the new tooth; *b*, the old; *c*, the jaw.

The student is referred to succeeding figures and descriptions, for a delineation of other portions of the structure of various reptiles. Thus, the vertebræ of the *ichthyosaurus* and *plesiosaurus*, which are ex-

tremely abundant, and are frequently found in the same deposits, may readily be distinguished by the more concave character of the former. As this concavity of form is a character approximating to the type of fish, the creature has hence received the name of *ichthyosaurus*, a term which imports that it was more a fish than a lizard; while that of *plesiosaurus*, indicates an animal which was more a lizard than a fish; the vertebræ of the latter being more elongated, and presenting a nearer approach to the lizard type.

The foregoing observations are, obviously, of the most general character, and we would refer the student who is desirous of farther information, to the following authorities, among others, viz.: the entire works of Cuvier, more especially his *Règne Animal*, his *Leçons d'Anatomie Comparative*, and his *Ossements Fossiles*, together with the writings of Dr. Mantell, particularly his Fossils of Tilgate Forest, and his Geology of the South East of England; as well as to the various papers and monographs of Professor Owen, in particular his Memoir on the *Plesiosaurus macrocephalus*, in the possession of the Earl of Enniskillen;* his Report on Fossil Reptiles, to the British Association of Science, and his splendid work on Odontography, now in course of publication. The writings of Dr. Grant on the same subject are similarly instructive.

Ichthyology.—The fossil fish form a highly interesting department of geological inquiry; the most important collections of these objects are, the general assemblage formed by the Earl of Enniskillen and Sir Philip Egerton, which has been selected from various

* Geological Transactions, vol. v. p. 515.

deposits, and that exhumed by Dr. Mantell, from the chalk.

As objects so fragile and perishable as fish seldom present the entire form, or general characters, for inspection, but occur, chiefly, in a fragmentary state, Professor Agassiz has classified the fossil fish in four orders, by an arrangement founded on the character of their scales—a method which has now been universally adopted.

I. The first of these comprises those of the placoid order, so termed from πλαξ, a broad plate, from having the skin *irregularly* covered with plates of enamel, sometimes large, sometimes reduced to small points, as in the stars and rays.

FIG. 197.

II. The second consists of the ganoid order, so called from γανος, splendour, because they are covered *regularly* with angular scales, composed of horny or bony plates, coated externally with a bright enamel.

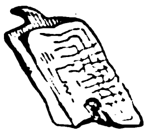


FIG. 198.

III. The third, or ctenoid order, from κτεις, a comb, includes such as are characterised by scales, jagged, or pectinated on the posterior margin, as in the perch.

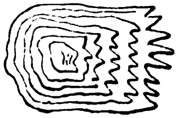


FIG. 199.

IV. The fourth order, that of cycloid fishes, from κυκλος, a circle, have scales smooth and simple on the margin, and often ornamented with various figures on their upper surface. The herring and the salmon are examples.

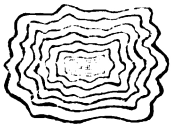


FIG. 200.

In these two latter orders, the scales are composed of laminæ of bone or horn, and are destitute of enamel. To the ctenoid and cycloid orders belong three-fourths of the eight thousand living species of fish. These orders first appear during the cretaceous period; nearly two-thirds of the species belong to extinct genera, and none are identical with those of any other system, either more ancient or more recent.

Trilobites.—These are a family of the order of *crustacea,* which became extinct at the close of the carboniferous epoch, no traces of their existence being

discernible in rocks of later date. They appear to have been extremely numerous during the comparatively brief period of their existence, twelve genera, and more than sixty species, having been established. In form they are divided, as their name imports, into three lobes, or parts; though in one genus, named by C. König, Esq., of the British Museum,* *homalonotus*, or smooth-backed, the two furrows which form the lobes are almost entirely obliterated, and the surface is nearly smooth. They present a great variety of form; and while some species could coil themselves up like a ball, as the *calymene Blumenbachii*, others had the central portion alone moveable, as the *asaphus tuberculatus*, and others possessed a tail, as the *asaphus caudatus*. They were remarkable for the absence of antennæ; and their feet, or paddles, are conceived to have been soft and perishable, from the fact that no remains of these organs have been discovered in a fossil state. But their most remarkable feature was the eye, which was immovable and fixed; while this apparent deficiency was compensated by an arrangement similar to that by which the fixed and sessile eyes of certain insects, as the house-fly, dragon-fly, and butterfly, are furnished with several thousand visual tubes. The eye of the

* The writer cannot refrain from usurping a permission, which he feels assured would never have been granted, that of recording, with the name of this gentleman, his private worth, as well as the assistance which he has rendered to science. His merits and attainments in the several departments of mineralogy, botany, conchology, and palæontology, are known and appreciated by the whole scientific public. It remains for one who has been for some years his assistant, to bear testimony to the honourable character, unswerving integrity, and dignified and generous feelings of the man.

trilobite was provided with many hundred lenses of this kind; and Dr. Buckland has availed himself of this interesting fact, in his Bridgewater Treatise, as affording an additional proof of design in the works of creation. The engraving below, from the admirable work of Dr. Buckland, will afford an idea of this singular structure.

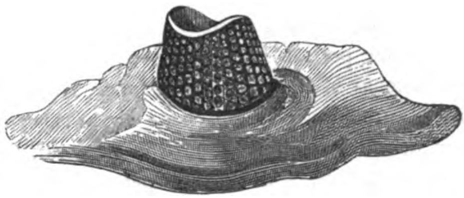


FIG. 201.—Eye of the Trilobite.

They chiefly occur in the Silurian deposits; and the reader is referred to a subsequent chapter, for the figure of a species characteristic of that formation.

THE CORALS.—We shall here deem it necessary to introduce a few remarks descriptive of the corals, both because their structure is frequently and commonly misunderstood, and because they have ever constituted, as is well known, a very important agent in the production of geological deposits. For more ample information, the reader is referred to the works of Lamouroux, and of Ellis; while a highly interesting and instructive description will be found in Dr. Mantell's Lecture on Corals, in his Wonders of Geology.

We occasionally hear persons who have not paid due attention to the subject, speaking of the labours of the coral insect, of the creature constructing its cells, and so forth, as if these operations were analogous to those of the bee building its cells; though there is, in fact,

no analogy between them; for, while the bee forms its structures for the purpose of storing its honey, the coral is an integral part of the animal, representing, in fact, its osteology, and being to the coral insect what the human skeleton is to our own frame. The economy of the coral is in general terms as follows:—The parent-mass, either by a division of its own substance, or by throwing out a gemmule or bud from its side, or some other portion of its frame, produces a small and infant-mass of gelatinous substance, studded with apertures, inhabited by polypes, or worms; which speedily attaches itself to a portion of coral, or rock, on which it grows, and becomes permanently affixed. The polypes obtain their food by the action of the *cilia*, or hair-like vibratile processes, with which they are furnished, and which, by their continual movement, bring within reach of the central mouth of the polype, fresh currents of water, charged with the animalcules on which the polypes exist. The minute mass gradually secretes an internal nucleus or skeleton of calcareous matter, and having, during its existence, given birth to other and similar colonies of polypes, the animal portion dies, and the gelatinous matter, with its families of polypes or worms, perishes, but the stony skeleton is left to form, by continual accumulations of this nature, those reefs and islands, which have ever constituted so important a feature in the formation of the varied deposits of our earth. The conditions, of course, vary, in the most essential degree, in the diversified tribes of this singular class of beings; the skeleton is sometimes internal, or, occasionally, external; of the nature of coral, of limestone, of wood, or of horn; sometimes lying as a prostrate mass of rock;

at others, growing as a stem, or branching into the most delicate ramifications; these conditions being dependent on the situation and mode of existence of the various genera; but in all, the same distinctive characters are preserved, of a skeleton, or support, and a jelly-like mass perforated with apertures, which are the abode of worms.

Coral Formations.—While the economy of individual corals has been thus explained and understood, numerous difficulties have still prevailed with reference to their general operations, in particular we may mention the anomaly, that while it is ascertained that the coral insect can only exist at a moderate distance beneath the waters, coral formations are found at very profound depths; while it appears alike difficult to account for the circular shape which these formations so constantly present. Mr. Darwin has, however, suggested a theory, founded on a very attentive observation of these objects, which serves to account, in a highly satisfactory manner, for all these seemingly contradictory phenomena. He assumes, that portions of the bed of the ocean, which are the site of the coral formations, have been, and still are, subjected to gradual submergence and elevation. The difficulty, therefore, of finding coral rocks at a greater depth than the coral insect could exist is removed by the supposition, that as fast as their structures were deposited, they were submerged by the subsidence of the ocean-bed on which they were formed. Again, the circular form of reefs and islands had been attributed to the supposition, that they had been constructed on the craters of submarine volcanoes; but, as some of these reefs are one hundred and fifty miles in

circumference, such a supposition was, of course, out of the question. Mr. Darwin, therefore, states, that the different varieties of the coral formations, whether occurring as flat, tabular islands; as fringes investing elevated land; as barriers protecting it at a distance, or, lastly, as annular reefs, are all referable to the two causes of elevation or depression above-mentioned; that where on the one hand, elevation has taken place, we have an island formed of coral rock, or surrounded by a fringe of that substance; that where, on the other, depression has occurred, we observe circular reefs, and isles of corals, which once girdled the previously existing island, now sunk beneath the waters; and, lastly, that longitudinal reefs indicate the submergence of lines of coast of which these reefs were previously the protecting barriers. The foregoing description may furnish the beginner with a general outline, and for more particular details, he is referred to Mr. Darwin's Journal, in the Voyage of the Beagle.*

ASTERIADES.—The star-fish is a genus of animals of the molluscous order. They have their mouth in the centre and placed downwards; from their bodies five or more rays or arms are given off, furnished with numerous retractile *tentacula*. They have the power of reproducing these rays if destroyed. They are marine, and are frequently found fossil.

CRINOIDEA.—The representatives of this tribe of creatures are of rare occurrence in our existing seas, having now dwindled down to one or two species, though the enormous range which they once occupied in the oceans of the ancient earth, may be estimated from the fact, that the *crinoidea* already discovered have been

* See also Proceedings of the Geological Society, No. 51, p. 552.

arranged in four divisions, comprising nine genera, most of them containing several species. They are placed by Cuvier, after the *asteriades*, or star-fish, in the division of zoophytes. Their skeleton is composed of numerous ossicula, the number of bones in one skeleton being computed at thirty thousand! The chief authority on their nature and structure is Mr. Miller, who, in his History of the Crinoidea, thus defines them. An animal with a round, oval, or angular column, composed of numerous articulating joints, supporting, at its summit, a series of plates, or joints, which form a cup-like body, containing the viscera, from the upper rim of which proceed five articulated arms, divided into tentaculated fingers, more or less numerous, surrounding the aperture of the mouth, situated in the centre of a plated integument, which extends over the abdominal cavity, and is capable of being contracted into a conical or proboscal shape. The column is conceived to have been covered with a coriaceous, or leather-like, integument. They resemble, in short, a star-fish, with a long flexible column attached at its base to a rock. The detached ossicula occur in myriads in the mountain limestone, and other of the lower secondary rocks, forming successions of strata many feet in thickness, and many miles in extent, showing how largely the bodies of this peculiar tribe of animals must have contributed to increase the mass of materials composing the crust of the earth. The accompanying figure depicts the pelvis and part of the stem of a species of *crinoidea*, frequently occurring in the *muschel-kalk;* a deposit appertaining to the new red sandstone formation, which, though not occurring in this country, is largely developed in Germany.

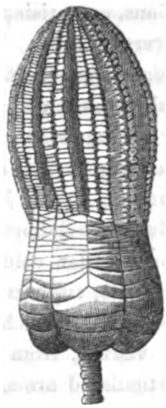


FIG. 202.—Encrinites moniliformis.

ECHINI.—These creatures are included in the order *echinodermata*, being covered with a thick coriaceous, or leather-like skin, and are called sea-urchins, or sea-eggs. Their shell is composed of polygonal plates, fitting closely to each other, and the surface is divided vertically by bands, having double rows of perforations, which, from their fancied resemblance to the walks in a garden, are termed *ambulacra*. The shell is studded over with papillæ, which vary in size in the different species, from mere minute points, to large distinct tubercles. To these papillæ spines are attached, whence the name *echinus*, or hedgehog, from their resemblance to the spines which cover that creature: these serve for purposes of locomotion, and present great variety of form and embellishment. They abound in existing seas; in a fossil state they occur very numerously in the chalk formation, and the reader is referred to the chapter which treats of those deposits for engravings illustrative of these objects.

SPONGES.—These form the second lowest class of animals between the polypifera, or corals, and the infusoria, or microscopic animalcules: their structure may be described, in general terms, as follows:—The sponge of commerce, or of domestic use, is the skeleton or support of the animal portion, which is a gelatinous or jelly-like substance, of so tender and perishable a nature, that the slightest touch is sufficient to tear it asunder, to allow the fluid parts to escape, and reduce it to a thin oily liquid. The surface of a living sponge presents two kinds of orifices, the larger, of a rounded shape with raised margins, which form projecting papillæ; the smaller, minute and numerous, constituting the pores of the sponge. The water enters through these pores, which are provided with a gelatinous net-work, and projecting spicula to protect them from the larger animalcules and floating particles of extraneous matter; the larger canals are thus incessantly traversed by streams of water, passing inwards through the pores, and discharged through the larger orifices, or vents, but no polypi, or cilia, have been discovered in these parts; though, judging from the analogy of corals and other zoophytes, we might consider them necessary and likely to occur.

THE INFUSORIA.—As these animalcular beings are not only objects of exceeding interest, as regards their organization and structure, but as their mineralized skeletons have contributed, in various instances, to form the solid strata of the earth, we shall here introduce some account of their nature. If we place a drop of any decayed infusion of animal or vegetable matter under the microscope, we discover in it various forms of living beings, some of a rounded, some of a length-

ened shape; and some, as those of the genus *proteus*, exhibiting ramifications shooting out in all directions, with such variety and swiftness, as to render it difficult, if not impossible, to determine their exact form. As they are the most minute forms of life with which we are yet acquainted, they were heretofore conceived to be lowest in organization, and to be destitute of either mouth or stomach. Professor Ehrenberg, however, who has devoted the utmost care and perseverance to their investigation, and has published the results in his splendid work *Die Infusions-thierchen*, has ascertained that these creatures, which were previously considered to be scarcely organized at all, possess an internal structure resembling that of the higher animals. He has discovered in them not only a mouth and stomach, and, in many instances, numerous stomachs, but also muscles, intestines, teeth, different kinds of glands, eyes, nerves, and sexual organs of reproduction. He has ascertained that some are born alive, others produced by eggs, and some multiplied by spontaneous divisions of their bodies into two or more animals. Their powers of reproduction, he states, are so great, that from one individual a million were produced in ten days, on the eleventh day four millions, and on the twelfth sixteen millions. In his work above mentioned. more than five hundred species are figured and described, and he has found them in fog, in rain, and in snow. Their connexion with geology, and the strata which their mineralized structures have contributed to form, will be described in a succeeding chapter.

EXERCISES

ON PALÆONTOLOGY.

1. Copy the abridgment of Cuvier's arrangement of the animal kingdom, and impress its leading features on the recollection.

2. Describe the structure of the teeth and jaws of the carnivora, herbivora, and rodentia, and give typical examples of each.

3. State, in like manner, the distinctive characters of the teeth of reptiles, with similar illustrations.

4. Mention the most remarkable fossil animals of the mammalian class, named in the foregoing chapter. Give the derivation of their names, and their distinctions of form, structure, habit, &c., &c.

5. Mention the geological deposits in which the most remarkable specimens have been discovered.

6. Name in what system of strata the remains of mammalia first occur; mention if there be any exceptions to this rule, and of what nature. (Turn for this object to the chapter on the oolite formation.)

7. In what systems of deposits do reptile forms of existence chiefly occur? Name the most remarkable examples of these, with their structure, character, presumed habits, &c.

8. Copy and commit to memory the arrangement of fossil fishes, proposed by Professor Agassiz.

9. Explain the trilobites, with reference to their usual form and most striking characteristics.

10. Detail the general character and habits of corals;

and explain the anomaly of stony corals being found at greater depths than those at which the animal itself is able to exist.

11. Describe the *crinoidea*, their structure, presumed habits, &c.

12. State the chief characters of the *echini* and *asteriades*.

13. Explain the nature of sponges.

14. Mention the *infusoria* under their various relations.

CHAPTER X.

GENERAL DIRECTIONS FOR THE STUDY OF THE SCIENCES PREVIOUSLY DESCRIBED.

As we have now detailed those pursuits which are of essential value and assistance to the geologist, we will next offer a few observations as to the most useful and beneficial mode of applying them to the practical study and acquirement of geological knowledge.

General Rules for the Study of Geology.— The science is so essentially one of speculation, its sphere of research is so decidedly the past and the distant, the remote and the unknown, that it becomes scarcely possible to prescribe the mode in which its inquiries should be conducted, comprising, as they also do, subjects of the most different and dissimilar kinds, and demanding correspondingly varied and diversified modes of pursuing them. The following rules may, however, be found to afford some assistance. While, on the one hand, the good sense and mental discipline of the student will instinctively induce him to reject such speculations as are absurd in principle and impracticable in operation; on the other, he will not be disposed to reject a theory because it may not, at first sight, coincide with his preconceived opinions. The maxim that *le vrai n'est pas toujours le vraisemblable* is one which is frequently realized in physical science; and in geological researches it often occurs, that of two hypo-

theses proposed for the solution of any given question, that which, at first sight, appears the least probable proves, on farther investigation, to be true; the fact being, not that nature deals in prodigies or miracles, but that our own minds are too accustomed to superficial inquiries and common-place observations, to be enabled to appreciate the depth of her causes, the magnificence of her operations, and the grandeur of her results. It will farther be found desirable ever to keep in view those leading general principles which all agree to value, yet all so commonly concur to neglect. Thus, it is expedient at all times to avoid hasty generalizations and universal conclusions, founded only on single and isolated phenomena; it is far wiser to be content for a time with collecting facts, and when a sufficient amount of well-authenticated data has been accumulated, to pronounce the decision in favour of that hypothesis which possesses the weight of evidence in its favour. It should ever be borne in mind, that, while in the school of nature, we are all learners, no one is a master; and that the object of all should be rather to acquire knowledge on those points of which we are ignorant, than to dispense imperfect intelligence on subjects respecting which we are only half informed. For instance, no testimony is more deceptive than that which is called negative evidence, and which is too often only the name for ignorance or want of observation. The student is, of course, aware that this phrase describes the assumption, that because certain phenomena have not occurred to our observation, they have, therefore, never had existence; the fact being, that they may have escaped our own researches, to reward those of others more energetic, or more successful than ourselves.

Thus, certain genera of molluscs, of which the *conus* is one, were, up to a recent period, conceived to be confined to the tertiary deposits; but more recent investigations have detected this latter form of life, extending as deep and as early as the lias; while, on the other hand, an ancient form of shell, the *spirifer*, was conceived to have become extinct with the lias, its only representative in that formation being the *s. Walcottii;* but a personal friend of the author, Mr. Buckman, of Cheltenham, has discovered several new and undescribed species in that formation; thus multiplying and extending the boundary of this ancient form of shell. And the age of reptiles, a supposition which was doubted and denied by the author of a work, as late in date and as eminent in authority as one of the Bridgewater Treatises, is proved, by the discoveries of a Mantell and an Owen, to constitute a period comprising the far greater portion of the history of the earth. Again; the student cannot too strongly impress on his memory the great and guiding principles of the science, the immensity of nature, the magnificence and power of her causes, the harmony and certainty of her operations, and the splendour of her effects. He should alike be aware of the necessity of constantly recurring to first principles, and of referring to those studies which form the basis of those inquiries to which his attention is directed. Thus, in studying mineralogy, he should bear in mind those laws of chemistry on which this science is founded, and should be anxious to investigate the nature and combination of those elementary bodies, the union of which constitutes the substance under review. In investigating physical geology, he should ever be careful to revert to primary principles and original conditions,

and should remember, as before stated, among other instances, that the rocks which it is his object to examine, were not always the hard, unyielding substances which we behold them now; but that all rock, all stone, and whatever now is hard, was once in a very different condition—that of sand, of mud, of fluid, or of vapour. In studying conchology, he should carefully bear in mind the zoological characters of this science, and should direct his views from the shells themselves to the living inhabitants by whom they were constructed, as a cover, shelter and protection. In fossil botany, he should revert from the plants of the primeval time to the analogous vegetation of the tropics; and from the structure and habits of existing palms, ferns, canes, and bamboos, should study the analogous vegetation of the ancient earth. In palæontology, a similar course should be pursued; existing laws of animal physiology, structure, and habits should be compared with those of primeval nature, and the present should be made the guide and interpreter to the past. By observing the above rules, and by constantly referring to first principles, primary causes, and original conditions, his progress in sound knowledge will be facilitated and assisted in an eminent degree; and, to borrow the beautiful image of a distinguished modern philosopher, Dugald Stewart, "his career will resemble that of a passenger navigating some waveless river, or calm unruffled sea. His progress may, for a time, be so gradual, that he may scarcely be aware of making any advance at all; but if he looks to the shore, he will find that some object which shortly before was in advance, he has either already attained, or has left far behind; while fresh objects dawn on his sight, and present new

spheres of inquiry and investigation." And thus he will continue to strengthen and invigorate his mental and moral powers by their continual use and employment; and imperceptibly, but surely, will increase his knowledge and love of nature, his distrust of himself, and his admiration of the divine and ineffable Creator.

A brief Sketch of Modern Geological Changes.—Before we address ourselves to the history of the past, we shall direct some attention to that of the present, and previously to describing the vicissitudes which the earth has evidently undergone in remote periods of its existence, we will devote a few pages to the account of those changes which have occurred in this country during the historical period, and the narrative of which is preserved to us by the national records. Our sketch will of necessity be brief; for to enumerate the whole of those mutations which have taken place during this comparatively brief period of the great history of the past, would require a separate and complete treatise.

We cannot direct our observations to the earth around us, without being aware of that metempsychosis of matter which forms the primary law of nature; and of that universal principle of change which is impressed on all created objects, as the condition of their existence. Every operation of nature, however familiar or minute, the heat and the cold, the moisture and the drought, the warmth of summer and the frost of winter, the snow and the ice, nay, every drop of rain that falls from the atmosphere, performs its share in displacing and renewing the solid crust of the earth, and contributes its allotted portion in carrying on the great work of universal metamorphosis and change. Professor Playfair was the first geologist of weight and influence in this

country, who divided these various agencies into a two-fold classification, that of destructive and conservative principles; though, as we have already shown, these phenomena were no new discovery of his own, but had already been noticed by preceding observers. As the most convenient arrangement which we could probably adopt, we shall pursue the inquiry chiefly in relation to the two causes under which he has arranged it.

As mentioned in a preceding chapter, the phenomena of nature had early engaged the attention of philosophic observers, and the enumeration of Ovid (see page 34) comprises the chief agencies in operation at this moment; such as the change of land to sea, and sea to dry land; the excavation of valleys; the destruction of hills, and the transfer of their materials to the sea; the transition of dry ground to marshes, and the reverse; the occurrence of earthquakes, and the phenomena they produce; the uniting islands with mainlands, the insulation of peninsulas, and in general those instances of change which characterize the varying condition of the crust of our globe. The laws of nature are of course as permanent as they are powerful, and the causes above described are as active and influential at present as they were twenty centuries ago, when the description was written. The sea, as a matter of course, is a powerful and active agent of destruction; and the shores of our native island from its most northern to its most southern points—from the primary deposits of the Isles of Shetland to the chalk cliffs and tertiary strata of Sussex and Kent, and thence to the Land's End and the western coasts, present the most extensive and fearful proofs of its power of devastation. We find, in every instance, that lofty

cliffs, promontories, and precipices, are in a state of destructioo, which is more or less rapid, in proportion to the more or less hard and crystalline character of the materials which compose them, and their relative power to resist the abrading force. The prevalence of currents constitutes a local cause which, in like manner, modifies the devastating power of the ocean. At the same time, bays and gulfs are prone to fill up from the accumulation of the detritus worn away from the neighbouring cliffs, so that depths continually vary, and the bed of the sea is liable to constant change of level and of depth. Commencing with the shores of Orkney and Shetland, we observe the effects of the waves on the primary formations of those distant isles; and proceeding to the main-land, we notice like traces of devastation along the eastern coast of Scotland, where tracts of land, villages, and towns, are recorded to have been swept away by the sea. On passing the English border, we find the coasts of Northumberland and Durham to present similar marks of destruction, which are recorded in the historical descriptions of these districts. On the shores of Yorkshire, the same scene of devastation presents itself; several villages have been lost, of which, in some cases, a mere vestige, in others the name only remains, the amount of denudation depending largely on the nature of the cliffs, and their greater or less capability to resist the waves. Thus at Bridlington, the cliffs of which are largely composed of alluvial deposits resting on chalk, a great portion of the quay has been swept off, and the remainder only waits the slow effect of time to share the same fate. Among other places the town and port of Ravenspur, at which Henry IV. landed on his enterprise of dethroning Richard II., now

exists only in the historical records of that event. The coasts of Lincolnshire are chiefly low, and are protected by embankments, the destruction of which by inundations, and the consequent incursions of the sea, have at various periods occasioned the most disastrous results. Tracts of this fenny district having been embanked and drained by the Romans, were lost after the departure of that people by the neglect of the embankments, and the consequent inroad of the ocean; and the recovery of these by draining has constituted a highly successful enterprise in modern times. A plan is now in contemplation for draining a portion of the Wash, as it is called, lying between the counties of Lincoln and Norfolk, by means of uniting the rivers Ouse, Nene, Witham, and Welland, into one broad channel in the centre of the Wash. The land which it is proposed to reclaim will equal in size a whole shire, and under the name of Victoria county, by its triumph over nature, and its accession to our national resources, will admirably commemorate the reign of that sovereign whose name it is destined to bear. The coasts of Norfolk and Suffolk, being composed of materials less capable of affording resistance than the harder substances of the more northern shores, exhibit a more striking example of the destructive powers of nature in the waste of the cliffs; while the deposit of bars and sand-banks, which are composed of the detritus thus produced, and which in many cases act as barriers to the sea, and prevent its farther encroachments, affords an equally obvious instance of the conservative principle already mentioned. While on the one hand tracts of land, manors, and villages, together with the old town of Cromer and of Dunwich, have been swallowed up by

the ocean; on the other, various districts have been won from the deep; and history and tradition record the fact, that the sea once extended up to Norwich, on an arm of which, it is recorded in Saxon manuscripts to have been situated, while ancient cliffs exist far inland which prove that the sea has receded still more considerably from its ancient limits. Extensive devastation is observed along the coast of Essex, which is largely composed of strata appertaining to the London clay formation; and the town of Harwich, which is stated to be the representative of a more ancient town, called Orwell, submerged beneath the deep, is in inevitable danger of sharing the fate of its predecessor by the same cause, the inroads of the ocean. The coasts which surround the estuary of the Thames, present like examples of the countervailing destruction and restoration of land. While the cliffs of the Isle of Sheppy, which consist solely of London clay, are constantly wearing away; so that in another half century, the island itself, it is conceived, will cease to exist; the channel which separated the then Isle of Thanet from the main land of Kent, has shoaled up so as to form marsh lands which now unite the two.

The Goodwin sands are reported by a well-known tradition to have constituted the estates of Earl Goodwin, which were submerged beneath the waves; and tradition, it may be observed, usually has some foundation in fact. Pursuing the inquiry along the coast of Kent, we find the work of devastation still continued, and the firmer cliffs of the chalk are undermined and destroyed as surely, though, doubtless, somewhat more slowly, than the more yielding strata of the London clay formation. The cliffs of Dovor are thus sapped, and considerable falls take place after any severe frost;

while at Folkstone, the same accidents are produced in a manner analogous to that which takes place at the back of the Isle of Wight, in strata of the same geological formation, and which has given rise to the celebrated Undercliff of that picturesque and instructive island. The chalk at Folkstone (in the Isle of Wight it is usually the green-sand) rests on the galt, or blue clay, and the water which penetrates through the chalk strata so moistens and lubricates the clay, as to occasion the overlying mass to slide down the inclined plane of the subjacent deposit, and thus to produce falls of enormous extent and importance. Along the coast of Kent, ground has alternately been won and lost from the sea. The cliffs of Hastings have suffered considerable destruction; as also those of the promontory of Beachy Head, where an enormous mass, three hundred feet in length, and thirty in breadth, was precipitated, some thirty years since, and similar falls have since repeatedly occurred. The chalk cliffs along the coast have undergone like abrasion and disintegration. At Brighton, part, though not the whole, of the ancient town was situated, in the reign of Elizabeth, under the cliffs, on the spot where the chain-pier now extends into the sea; and, in the year 1665, twenty-two tenements had been ingulfed by the waters, but one hundred and thirteen still remained, which were destroyed by the great storm of 1705. The waste still continues; the road called the Marine Parade has repeatedly been narrowed; a battery formerly stood at the bottom of the New Steine, the site of which is now swept away; and the writer's father recollects another battery, which was erected on the beach at the back of Mahomed's baths, and was destroyed by a tempest in 1784. Groins

and sloping walls have been erected at a vast expense, at the public cost, which form a protection to the town itself; but as the cliffs to the eastward waste in a rapidly increasing rate, in consequence of the force of the ocean being thrown back on them, the probability is, that in the slow progress of ages, the town will be rendered a peninsula, and the queen of watering places terminate her reign in the depths of the ocean, leaving her then inhabitants to follow the example of their ancestors, and erect a new town, farther removed from the power of the sea, which in its turn will alike be submerged beneath the waves which have destroyed its predecessor. Proceeding westward along the Sussex coast, we find various instances of land having been in like manner ingulfed, and our attention is drawn to the circumstance of several large churches, built in the immediate vicinity of the sea, which are extremely disproportioned, as to size, to the scanty population by which they are surrounded, and the revenues of which are remarkably small, owing to the lands with which they were endowed having been swallowed up. We have already alluded to the mode in which the cliffs of the Isle of Wight are sapped, and what may be called landslips of the cliffs are produced; and it may be observed, that the promontories and headlands are usually composed of strata appertaining to the chalk formation; while the bays, as Alum Bay, Sandown Bay, and others, are hollowed out, either of the more destructible substances of the tertiary strata, or the equally yielding beds of clay belonging to the wealden series of deposits.

In investigating the western coast, we find the same conditions to prevail; the bays and coves are scooped out of softer deposits, while the harder rocks, which

have withstood the action of the waves, constitute the promontories and headlands. These last are in continual course of abrasion, their destruction being observed to be more rapid in all cases where the substratum, as in the cliffs at the back of the Isle of Wight, consists of clay, which being lubricated by the rains, causes the overlying mass to fall, or rather to slip over the bed beneath. Such is the case as regards the peninsulas of Portland and Purbeck, and a similar agency is observable at Lyme Regis. The great landslip of Dec. 24th, 1839, which occurred on the coast between Lyme and Axminster, was produced under these circumstances, the upper-beds consisting of strata belonging to the chalk and green-sand formations; the lower being composed of clay appertaining to the lias. The effect of springs existing in the green-sand had previously been to loosen the upper beds, and by moistening the clay, to produce frequent falls, forming a kind of undercliff. On the present occasion, the season had been unusually wet and rainy, and the upper strata having become saturated with moisture, and, consequently increased in weight, while the lower deposits had been rendered slippery, the entire mass was set in motion, and the whole of the beds above the lias, comprising masses of chalk, chert, and green sand, were gradually precipitated over the subjacent beds of lias clay. The neighbouring coast of Devon presents marks of like action; but, owing to the firmer nature of the rocks of that district, consisting largely of sandstones and limestones, appertaining chiefly to the old red sandstone and mountain-limestone, the action of the waves is less striking, and appears to have been less rapid; while on the adjacent shore of Cornwall, the still harder and more crystalline character of the primitive rocks, the granites,

syenites, greenstones, and the like, evince feebler marks of the agency of the sea, and no perceptible change, of any extent or importance, with some trifling and local exceptions, is recorded as having taken place in the configuration of the coast, during the records of man. The general principles, however, which are remarked in other localities are observable here; the softer rocks being gradually hollowed out into creeks, coves, and bays, while the harder are left to protrude as points, precipices, and headlands; the results being proportionate to the various causes arising from the unequal resistance of the rocks, the power of currents, tides, waves, and breakers, and the original form of the land. Proceeding round the Land's End, the same description will apply to the northern coast of Devon, the shores of Somersetshire, and the adjacent district of Wales. On the Cheshire shores, the abrupt cliffs, composed of the softer clay and red marl of the new red sandstone system, have yielded, in an immense degree, to the advance of the ocean, and though in the estuary of the Severn, land both in Somersetshire and Gloucestershire, has been added, to a considerable extent, from the ocean, yet the loss on this part of our coasts far exceeds the gain.

It has already been observed, that the operations of the sea are materially assisted by the action of springs, the percolation of rain, and the operation of frosts. Where the cliffs, instead of being of homogeneous nature to their base, are composed, in their lower portions, of a permeable substance, such as clay; the upper portions are increased in weight, by the infiltration of moisture, while the lower are lubricated and rendered so slippery that the upper masses glide down and occasion a slip or fall. Frosts

prove a like important agent of destruction, fracturing, by the expansion of the water into ice, various portions of the mass, and detaching them into fragments, which fall to the base. The cliff thus attacked at the various points of its summit and its centre, by the action of water and of frost, and at its base, by the sea, becomes an easy and rapid prey to its various antagonists; and we may, from a due consideration of these causes, cease to wonder at the vast and extensive waste observable on all the less resisting strata, from the coasts of Yorkshire to those of Sussex, and thence, to a greater or less extent, to the shores of Cheshire and the coasts of Scotland.

While such are the results observable on our native shores, the same effects are perceptible over the entire globe; they are apparent on the opposite coasts of France, and are still more remarkable in Holland, a country, the very existence of which may be said to be dependent on that of man. But for his interposition, the whole region never would have been reclaimed from the deep, and were he banished from the earth, and the defences against the ocean which he has erected and maintained left to decay, it would survive him but a brief period, and would become immerged in the ocean, from which he has redeemed it, while the sea would proceed on its course to sap and level the mountains of the Rhine and the Alps, and, by degrees, the whole continent of Europe. To enumerate all the instances of the destructive effects of the ocean, observable over the whole earth, would obviously far transcend our limits; and it may be sufficient to mention, as the summary of our remarks, that the same principles universally prevail, of the harder rocks standing out as headlands, after the softer deposits have been worn into creeks and bays;

the action of the sea, as before mentioned, being modified by the local causes of the form of the land, and the action of tides, waves, breakers, and currents.

FLUVIATILE ACTION.—The agency of rivers is alike destructive of the banks through which it flows; and in the case of floods, torrents, and inundations occasioned by rains, tempests, the melting of snows, &c., the ravages thus effected are perfectly astounding to those who may not previously have directed their attention to these phenomena. We shall omit any detail of their action, for the reason, that, as these phenomena are more strikingly developed on the continents of Europe and America, the rivers of which constitute the drainage of larger tracts of country than is the case in our own islands, we shall refer to the excellent treatises of Lyell, Delabeche, and others, in which they are discussed in the most ample and satisfactory manner.

ATMOSPHERIC AGENCY.—The agency of the atmosphere, and of the vapours and rain which it produces, as already observed, is both chemical and mechanical; the chemical action being to disintegrate and destroy the rocks, by absorbing oxygen and carbonic acid from the air, by which absorption, rocks of all classes, are speedily weathered, and, in some measure, worn away. The mechanical agency, as already stated, consists, in the first place, in the abrading force of running water, by which the solid materials of the earth are continually worn off and transferred to the beds of adjacent seas; and, in the second, in the fissuring and cleaving rocks, by the expansive power of frost.

As the destructive agencies above mentioned are chiefly referable to degrading causes, and are attributed to the action of water, so those of renovative nature

are to be assigned to elevating forces, and are principally to be ascribed to the agency of fire; it being to these antagonist forces, as we have before stated, that the Almighty has delegated, in an important degree, the task of changing, modifying, and preserving the solid crust of the earth. The agency of heat is manifested, either by the rapid effects of the volcano, or the slower effects of gradual upheaval; the former being exemplified by the raising Monte Nuovo in a night, the latter by the uplifting of Sweden and part of Scandinavia by the slower process of continental elevation, the general geological effects of volcanic action being, as before observed, to raise the materials on which its influence is exerted, from a lower to a higher level.

The conservative principle is also exemplified in the tendency of the materials derived from the destruction of pre-existing rocks, to become consolidated into new strata, by means of cement, either of siliceous, calcareous, or ferruginous nature. The production of silex, which, it is observable, is far more abundant in the older formations than in those of more recent date, constitutes a problem which the present state of our knowledge by no means enables us positively to determine. But the siliceous deposits of the springs of Carlsbad, and, in particular, of the Geyser springs of Iceland, would seem to evince that they are due to the action of thermal sources and streams of hot water, produced by the internal heat of the earth, which may be presumed to have been more active and influential at the earlier periods of the earth's history than at present. The nature of calcareous cement is far more clear and easy of explanation. Most fresh water, it is well known, holds a certain quantity of carbonate of lime in solution, which,

by a change of temperature, is liable to be wholly, or in part, precipitated; the *fur*, as already observed, which lines the tea-kettle, affords an example of the process. Streams thus impregnated flowing over loose materials, as sand, pebbles, &c., would have the effect of cementing them into rock, and producing limestone, calcareous sandstone, or conglomerate; while waters holding iron in solution would, in like manner, cement similar substances into conglomerations of ferruginous nature. Iron, it is well known, constitutes, by the oxydation or rust of the metal, a cementing agent of very considerable power, as is evinced by innumerable facts, among which may be mentioned a grappling iron, preserved in the British Museum, imbedding a mass of beach. The same phenomenon is shown by various iron objects from the wreck of the Royal George.

Rivers exemplify the conservative or compensating principle, by the forming of deltas, or accumulations at their mouths and points of junction with the sea, by which the materials which they have abraded and carried off from the lands over which they have flowed, are thrown down in the shape of fresh deposits. The most striking instance is furnished by the Delta of the Nile; and the large rivers of the American continent, in like manner form similar deposits, which, from the fresh and virgin character of the new-formed soil, are remarkable for their fertility and productive power.

In addition to these mechanical agencies, we have already called attention to the fact, that vital action is alike employed in the construction of new deposits, and the formations of fresh spheres of habitation for animals and for men. The coral insect is, ceaselessly, at work rearing, first, its reefs, then its islands above

the surface of the deep, and, finally, by the union of these, producing continents, which, at a future period, will rival those already in existence.

The limestone of Guadaloupe, celebrated for the human skeletons which it embeds, is a recent deposit, formed by the following process. The coral reefs which surround the island are worn and abraded by the incessant action of the waves, and the detritus thus occasioned is wafted to the shore in the state of coralline sand or mud, where, by the action of the atmosphere, or of streams holding carbonate of lime in solution, the mass becomes indurated into a compact limestone. It is quite evident that the rock was in a soft and yielding state when these skeletons were placed in it, and it is also ascertained, that the bones are not fossilized, but retain their gluten and phosphate of lime. There is scarcely sufficient evidence as to the exact mode in which they have been imbedded, whether they are relics of a battle, or were deposited as a mode of interment. It is, however, conceived, that they may, in all probability, have been placed here for burial; for though General Erneuf, a French military officer, mentions a battle and massacre of the Gallibi tribe by the Caribs to have taken place, 130 years since, on this spot, yet Dr. Moultrie, an American *savant*, who possesses the head belonging to the specimen in the British Museum, declares it to be that of a Peruvian, or a race possessing a similar form of skull. A skeleton, now in the Museum of Natural History at Paris, was discovered in a sitting posture, which is known to be a usual position of interment among the aborigines of these regions. The accompanying figure depicts the object in the British Museum.

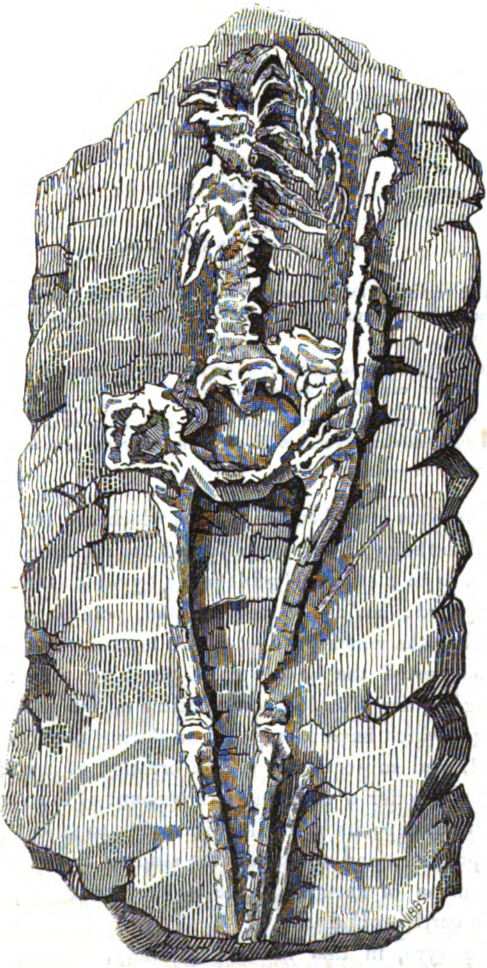


FIG. 203.

CHAPTER XI.

TERTIARY SYSTEM.

TERTIARY SYSTEM, SUPRACRETACEOUS GROUP OF ENGLISH; TERRAINS DE SEDIMENT SUPERIEURS OF FRENCH; TERTIAERGEBILDE OF GERMAN AUTHORS.

AUTHORS: LYELL, CHARLESWORTH, WEBSTER, SCROPE, HORNER, CUVIER, BRONGNIART, CONSTANT PREVOST, &c. &c.

COLLECTIONS: GEOLOGICAL SOCIETY, THOSE OF MR. BOWERBANK, AND MR. SAULL, PRIVATE CABINETS IN SUFFOLK, NORFOLK, ISLE OF WIGHT, LONDON.

HAVING thus described the studies which are most essential to the geologist, and afforded the requisite information as to the most eligible mode by which they may be acquired; having, it may be said, pointed out the several paths which conduct to the temple of geology, and suggested the best way of pursuing them; and having farther afforded some outline of the geological changes which have been going on during the historical period, and subsequently to the creation of man; we shall now offer a compendious account of the various systems of deposits in detail; with a view to unite theory with practice, and to enable the student to realize the phenomena of natural science, as they are exemplified in the earth around us.

The tyro, in this interesting study, will find his inquiries materially lightened and assisted, by adopting

a kind of *memoria technica*, or artificial memory; and, by impressing on his recollection, at an early period of his studies, some few striking facts, characteristic of each specific formation, by which it may be distinctly ascertained and recognised. Thus, the vast and varied deposits, fluviatile, lacustrine, marine, and volcanic, which make up the system of the tertiary strata, may be distinguished by the following general features, which it will be advantageous to remember.

1. They are all deposited in hollows, or depressions, usually of the chalk, and occasionally of older rocks.

2. They evince proofs of important changes in the relative level of land and sea, during that period of the history of the earth in which they were deposited.

3. They afford like evidence that, during the same epoch, this part of Europe was the site of enormous lakes, which, at the present day, have no analogy in this part of the globe, but which have their type in the vast lakes of the continent of America.

4. They likewise show that volcanic agency was developed at this period on a vast and magnificent scale.

5. They testify the gradual refrigeration which took place during this era, and the approximation consequent on the change of climate, to the forms of vegetable and animal life prevailing at the present day. Thus, while the dicotyledonous plants first assume their present preponderance in these deposits; animals of the class mammalia, that is, such as give suck to their young, first appear in any numbers on our earth.

6. Finally, owing to their position at the surface, and their having undergone less pressure than the rocks beneath, they constitute a vast depository of fossil shells,

which are preserved in such number and perfection, as to form a scale by which the relative age of these formations is usually determined.

CLASSIFICATION OF MR. LYELL.—At an early period of the science, a very inadequate idea of these strata was formed, it being conceived that they were all spread over one plane, and all deposited at one epoch. Subsequent researches, however, satisfactorily showed that, like the secondary rocks beneath, they were placed in the order of super-position, and were referable to very different periods. From a careful examination of the shells of the entire series, Mr. Lyell was enabled to classify the beds under some three or four general divisions, founded on the relative number which they respectively contained of such shells as were identical with existing species. To explain. In certain deposits he found that of a hundred shells there were no more than three which were identical with living forms; in other beds the proportion increased to seventeen in a hundred; while, in others, the numbers varied from about thirty-five to upwards of ninety, till, in fact, almost the whole of the shells were of now existing types. Inferring, therefore, as a matter of course, the relative age of these deposits to be determined by the amount of existing shells which they respectively contained, he assigned the three per cent. beds to the oldest term, calling them *eocene*, which may be considered as indicating ancient, from the Greek words Ηως, the dawn, and καινος, new, indicating the dawn of the new or recent period; the seventeen per cent. to the *miocene*, or middle, from μειον, less, and καινος, signifying that these beds contained a minority of recent shells; and the remaining deposits to the *pleiocene*, or modern,

from πλειον, more, and καινος, showing that these deposits contain a majority of recent shells. He subdivided this latter class again as follows:—the beds which contained some fifty per cent. of existing shells were termed older pleiocene, while those which presented ninety in a hundred of living forms were named newer pleiocene, or occasionally pleistocene.

It might possibly have been more expedient to have adopted such terms as would have expressed more distinctly than the names above cited the progressively modern character of these deposits, which is of course their most striking feature; and this might easily have been effected by avoiding the word *miocene*, and retaining *eocene*, *pleiocene* and *pleistocene*, signifying the degrees of comparison of the adjective new, newer, newest. But it is now too late to attempt this alteration, since the terms are so firmly established by the writings and labours of Mr. Lyell, that any endeavour to alter them would only produce more evil than advantage. The English reader will best understand the whole as signifying ancient tertiary, middle tertiary, and modern tertiary, subdividing these last into early modern tertiary, and later modern tertiary, or modern tertiary No. 1 and No. 2.

Objections to the System.—Objections of varied kinds have been adduced against the per centage system, as it is sometimes called, of Mr. Lyell, the chief of which are founded on the present imperfect state of our knowledge of conchology; and it has been urged that the determination of the species of shells, a decision which must, in a great measure, depend on the knowledge and skill of an individual

conchologist, affords a basis too insufficient for a generalization so extensive as that of determining the age of entire systems of deposits. In defence of the method, however, it may be argued that it is intended rather as an approximative than as an exact scale; and farther, that it has now stood the test of several years, during which the data adopted at an early period have, in their most important features, been confirmed and strengthened by the observations of separate and independent inquirers. It may be hence assumed as a fair and legitimate conclusion, that this system, if it is not to be regarded as truth itself, affords a closer and more perfect approach to the truth than it is possible to obtain without its assistance.

GEOGRAPHICAL DISTRIBUTION OF THE TERTIARY STRATA.—They prevail extensively in this country, but are still more largely developed on the continent of Europe, occurring in France, Italy, Sicily, Germany, and being recognized alike in every other quarter of the globe, as Asia, Africa, America, and Australia.

In Scotland, certain deposits occur in the basin of the Clyde, which from their relative proportion of existing shells, are referable to the newer pleiocene or pleistocene. In England the crag deposits (so termed) of Norfolk and Suffolk are also recognized as of similar character. The order and succession of these beds of the crag are somewhat complicated and difficult to determine, and hence they formed for some time a subject of considerable controversy and doubt. Mr. Charlesworth, however, in a memoir submitted to the British Association of Science in 1836, proposed an arrangement which, after some discussion, was recognized by

Mr. Lyell* as indicating their correct characters. This arrangement, following a descending order, is as under: 1st, and uppermost, lacustrine strata, containing mammalian remains; 2dly, the mammaliferous or Norwich crag; 3rdly, the red crag; and 4thly, the coralline crag. The red crag is so called from being of a deep ochreous colour. It consists chiefly of quartzose sand, with occasional intermixtures of rolled and fragmentary shells; and from containing about sixty per cent. of recent species is referred to the older pleiocene. Bones and teeth of the mastodon, elephant, horse, and other mammalia, have been found in these upper beds of the crag; and Mr. Lyell and Mr. Charlesworth state the characteristic shells with others to be

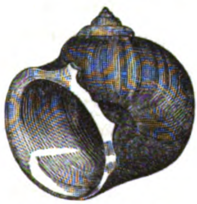


FIG. 204.—Natica glaucinoides.

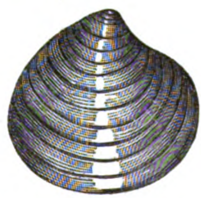


FIG. 205.—Astarte plana.

The lower and older of these divisions, from the great number of corals which it contains, is called the coralline crag, and from its presenting a much smaller proportion, about twenty per cent. of recent shells, is referred to the miocene or middle period. The beds are of limited extent, about twenty miles in length and three or four in breadth, and are usually calcareous and marly. Among the bones and teeth are those of a large species of shark termed *carcharias*, while the following, among

* See Magazine of Natural History, July, 1839.

others, are stated by the same authorities to be characteristic shells.

FIG. 206.—Voluta Lamberti.

FIG. 207.—Fusus contrarius.

While the basin of the Clyde thus affords an example of the newer, the upper or red crag of the older pliocene; and the lower or coralline crag of the miocene strata; the eocene or oldest beds of the system are supplied by those of the London and Hampshire basins.

The deposits which occupy the basin of London and the whole valley of the Thames fill up a vast gulf or depression of the chalk, which, commencing from the North Downs on the south, terminates on the east with the Isle of Sheppey, on the west with the sea, and is bounded on the north-west by the re-appearance of the chalk in the hills of Berkshire, Wiltshire, Oxfordshire, Buckinghamshire, and Hertfordshire. The whole of these accumulations were once divided into three distinct groups, the Bagshot sand, London clay, and Plastic clay, but, by later observers, they have been reduced to two; the first consisting of those superficial beds which compose the sands of Highgate, Hampstead, Finchley, Bagshot Heaths, and other arenaceous de-

posits in the vicinity of the metropolis; while the second comprises those underlying deposits of shingle, clay, loam, and sand, which constitute what is now called the London clay formation. The upper portion is composed of indurated clays, of various tints, chiefly bluish or brown, and frequently contains ovate nodules, or concretions of argillaceous limestone, divided by fissures, which are filled with veins of crystallized carbonate of lime, or sulphate of barytes, radiating from the centre to the circumference. They have been produced by the shrinking or cracking of the clay when drying, and by the infiltration of the mineral substance into the cavities thus occasioned. They were formerly regarded with extreme interest and wonder, and were termed *ludus helmontii*, but from presenting those appearances of division just described are now named *septaria*, from *septum*, a chamber. They are extensively used for cement, and in breaking them for this purpose, some organic substance, as a shell, a plant, or a fruit, is usually found to constitute the nucleus of the mass.

FIG. 208.—Septarium.

The lower division is composed of those alternating beds of sand, shingle, clay, and loam, which, from some of the clays being used for pottery, occasioned the name of the Plastic clay formation to be bestowed on the entire

series. The nature of their embedded fossils proves the marine origin of these deposits. The teeth and vertebræ of sharks, the crabs, lobsters, and other crustacea, together with the corals and marine mollusca, attest the strata in which they are found to be the bed of an ancient sea; while the terrestrial remains, though comparatively few, the leaves, fruits, and stems of plants, with masses of wood perforated by the *teredo*, evince the proximity of land, and show that these objects have been transported by rivers and tributary streams to the then existing ocean.

The cabinets of the British Museum contain a highly interesting collection of specimens of the London clay, formed by the late Mr. Swan, and presented by the widow of that gentleman.

The Isle of Sheppey.—This is considered an outlier of the same formation, being composed of London clay, which is so strongly impregnated with iron pyrites as to render the contained fossils extremely liable to decomposition, and to compel the collector to have recourse to particular methods, such as boiling them in linseed oil, or keeping them in water, in order to preserve them. The fruits of this locality are so abundant, that Mr. Bowerbank has commenced a work devoted exclusively to their illustration. They are all of a tropical nature, and constitute so important a characteristic of this peculiar region, as to have given rise to numerous conjectures as to the circumstances which have produced them. By some the district has been supposed to have been the site of numerous spice-islands; by more recent observers, it has been regarded as an estuary deposit, and the fruits are conceived to have been wafted by a river from the land.

The characteristic shells of the London clay are, among others,

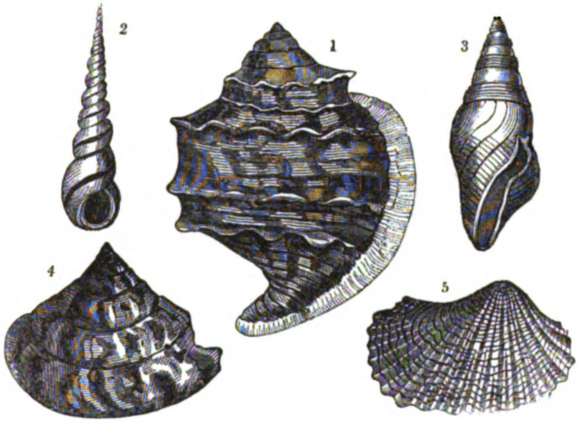


FIG. 209.—1. Cassis carinata. 2. Turritella edita. 3. Pleurotoma prisca. 4. Trochus agglutinans. 5. Arca interrupta.

Various parts of the London clay formation present the fossils termed *nummulites*, from the Latin *nummus*, a coin, to which they are supposed to bear some resemblance. They are conceived to have been the internal shell of a mollusc, and, from being capable of inflation, to have acted as a buoy, enabling the animal to sink or swim at pleasure.

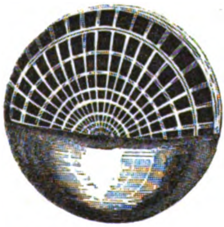


FIG. 210.—Nummulite.

We have previously mentioned a fossil substance, which has before been pointed out by Mr. Lyell, as an object highly interesting and instructive, and affording, by its history, considerable insight into the condition of the ancient sea and land.

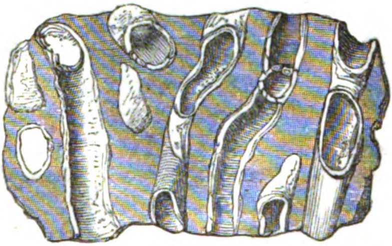


FIG. 211.—Wood perforated by the Teredinæ.

The above illustration represents a specimen of this kind, a piece of fossil wood, pierced by a boring worm of extinct species, called *teredina*, but allied to the *teredo*, the shipworm which proves so destructive to the timber of our vessels at the present day. The wood is now converted to a stony mass, a mixture of clay and lime; but Mr. Lyell observes, "it must have once been buoyant and floating in the sea, when the *teredinæ* lived upon it, perforating it in all directions. But before they settled on the wood, the branch of a tree must have been floated down to the sea by a river, uprooted perhaps by a flood, or torn off and cast into the waves by the winds; and thus our thoughts are carried back to a period, when the tree grew for years on dry land, enjoying a fit soil and climate." The induction might be carried even still farther than it has been pursued. A river supposes tributary streams, and these the

alternations of hill and vale, and the varied surface of a country of which these waters formed the drainage; while the condition of the atmosphere and of solar light and heat must have been analogous to their state at the present day, to have produced plants similar, as these specimens usually are, to those now existing around us. Thus, as in other instances, the whole panorama of the ancient earth and its productions might be restored, in all the reality of life, by the aid of the sure and unerring conclusions, suggested by a single and seemingly unimportant object, derived from a peculiar period of the great history of the past. It is a singular feature in the economy of these creatures, that though they approach so closely to each other in their perforations, as often to leave but a mere filament of wood between, yet they never actually break into each other's path; and a passage of Scripture, descriptive of the similar instinct of the locust, has been applied to depict their habits in this particular. "They march every one in his ways, and they break not their ranks; neither does one thrust another; they walk every one in his path."*

To the above remarks we may perhaps be permitted to add, that as the animal of this shell secretes and deposits, in the wood, a shield or tube for its protection, Sir I. Brunel is stated to have adopted the idea of perforating the bed of the Thames by defending his progress with a shield, from the example thus taught him by the operations of this apparently unimportant and insignificant worm!

Basin of Hampshire and the Isle of Wight.—We described the strata of the London Basin as being wholly marine, and exhibiting no example of any freshwater deposits. But in the adjacent districts of

* Joel, ch. ii. v. 7 and 8.

Hampshire and part of the Isle of Wight, we find such alternations of freshwater with marine beds, as indicate those important changes in the level of the land and sea to which we have already alluded. This phenomenon of the change of sea to land, and its reversal, is one of universal extent and influence, affecting, in fact, every portion of the surface of the globe, and as its operation has but recently been understood, it may be expedient to devote a brief space to its explanation. Since it was evident, from the earliest observation, that the existing land had once been sea; it became the practice, as we have already mentioned, at a former period of the science, to explain the phenomenon, by conceiving that the sea had retired, while the land had retained its position. Yet since it appeared that the same spot had, in many cases, obviously been the site of sea and land, under the varied conditions of ocean and æstuary, and of dry land, river, and lake, it became necessary to conceive several successive retirements and returns of the ocean. But while such a supposition was scarcely sufficient to explain the problem, as regarded the sea, it not only proved inapplicable to the land, but the land itself, far from affording evidence of having always remained in a tranquil position, offered in its dislocations and disturbances; its fractures and fissures; its elevations and subsidences, incontestable proofs that the earth itself had been the scene of the changes in question, and that their occurrence was to be explained by alterations in the level of the land, and not of the sea.

Temple of Jupiter Serapis.—The fact that the land has been raised, and not the sea lowered, has received abundant confirmation by the celebrated antiquarian remains above-mentioned, which have been so amply described by Mr. Lyell, Dr. Mantell, Mr. Bab-

bage, and others, as to require no more than a casual mention here. In the bay of Baiæ, near Naples, some pillars and other fragments of a Roman building were long known to exist. They were conceived to be the remains of a Temple of Jupiter Serapis, and though modern antiquaries have shown, that the worship of that Egyptian deity was proscribed to the Roman people, at the period presumed to be that of their erection, and that these relics are, probably, the ruins of an extensive suite of *thermæ*, or baths; the original name is retained for the sake of convenience. After having excited, during a considerable space, the interest of the antiquary, the attention of the naturalist was drawn to the phenomenon of certain perforations exhibited in the three remaining pillars, at about twenty feet from the ground. It is well known that there are shell-fish, the instinct of which is to bore into calcareous stones and rocks, and to exist in the apertures thus made. We often find masses of chalk, for instance, on our shores, perforated by animals of this kind, and presenting holes in which we may place our fingers; the markings of these columns have been effected by an animal of the same class. These creatures can, of course, only exist in the salt-water of the ocean, and from this, and other facts, it has been demonstrated that the columns in question have suffered since their erection, a submersion beneath the sea and a subsequent elevation of, at least, twenty-three feet, such being the height of the upper band of perforations. The phenomenon is ascribed to the operation of the volcano, the whole district around being volcanic, and the rise and submergence being attributed to the shrinking and expansion of the strata on which the structure was erected.

FIG. 212.—Temple of Serapis.

The movement appears to have been extremely gradual, for it has recently been ascertained by Italian geologists, that the pillars are actually sinking again, owing to the submergence of the soil; yet so gentle, so imperceptible are these motions, both of rise and fall, that the shattered columns of a ruined temple have not been overturned by their operation.

Rise of Sweden.—The phenomena observed in this single instance, and on a limited scale, have been verified by observations in various districts, and spreading over extensive areas. Mr. Lyell having first expressed his doubts of the alleged fact of a rise of land in Sweden; satisfied himself by a visit to that country that it was then, and had, for ages, been in course of ele-

vation in some places, and of depression in an opposite direction; in fact, in a state of oscillation, rising in the northern, and sinking in the southern parts. He arrived at these conclusions, not only from having ascertained that the land stood higher above the sea, at the period of his visit, than had been the case some twenty or thirty years previously; but by discovering beds of oyster-shells of existing species, in inland cliffs some distance from the sea, he farther inferred that the rise of land had been for centuries in operation.

While this phenomenon has been noticed in a general way in Sweden, it has been observed with still greater accuracy in Italy, and its progress determined with a correctness never before effected; Signor Nicolini, a geologist of Naples, having ascertained that between 1823 and 1838 the west coast of Italy has risen 112 millimetres, about four inches English, above the level of the sea.

The effect of earthquakes is frequently to occasion oscillations and changes of level; thus, as already mentioned in the visitations of 1822 and 1835, the whole coast of Chili, from the Andes far out to sea, comprising an area of 100,000 square miles, equal in extent to one half the kingdom of France, was raised to a considerable extent; and in the late fearful earthquakes which desolated the West India Islands, that of Martinique has changed its level, and undergone an oscillatory movement, being on the northern side, two feet higher above high water mark, and on the southern, two feet lower, than was the case prior to the occurrence.

Hampshire and the Isle of Wight.—To resume our description of these highly interesting localities, Mr. Webster has classified the tertiary beds of the Hampshire and Isle of Wight basin, in the following

subdivisions, commencing with the lowest. 1st. Plastic sands and clays. 2nd. The London clay. 3d. Fresh water deposits, consisting of sandy, calcareous marls, with large quantities of freshwater shells. 4th. Clay and marl abounding in marine shells, very generally of different species from those in the London clay. 5th. Upper freshwater deposits; yellowish white, or green marl, and calcareous limestone, employed for building, and forming almost one entire mass of freshwater shells, the chief forms of which are depicted below.

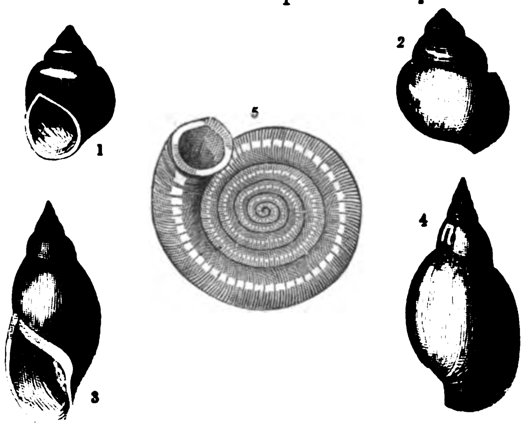


FIG. 213.—No. 1 and 2. Paludina concinna. 3 and 4. Lymnea pyramidalis. 5. Planorbis equalis.

This series of the tertiary beds is of considerable extent. Small portions occur near Newhaven, and Seaford, in Sussex : while, to the westward of Brighton, the London clay rises to the surface beyond Worthing and forms the tract between the chalk-hills and the sea. The inland boundary stretches by Chichester, Emsworth, and Southampton to Dorchester; and the clay extends over the New Forest, and as far as Poole,

being surrounded by the chalk on all sides, except the sea. The Isle of Wight is, in part, composed of strata of the same character, being, in fact, a disrupted mass of the formations of the adjacent south-east coast of England. By the agency of this disruption, the strata have undergone the most singular disturbances and dislocations, the chalk itself has been brought to a vertical position, has been actually lifted upright, and the super-imposed tertiary strata with it. These results are clearly displayed at Alum Bay, which presents the phenomena of sands and clays of the most varied tints, green, yellow, red, crimson, ferruginous, white, black, and brown, all lifted to a perpendicular situation, and having suffered no change, except that of having been raised, with the chalk, from a horizontal to a vertical position. Masses of lignite, the brown or imperfect wood-coal of the tertiary deposits, also occur in these beds, and are occasionally washed out of the cliffs and wafted on the adjacent shores of the main-land. In the limestone quarries of Binstead, near Calbourne, and at Morley, teeth and bones of *anoplotherium*, *palæotherium*, *chœropotamus*, and *dichobune*, creatures peculiar to these formations, the most important of which will be farther desciibed a few pages hence, have frequently been discovered. The Isle of Wight forms a highly interesting epitome of the whole of the formations existing in the south-east of England, comprising the marine tertiary deposit of the London basin, with freshwater strata not occurring in that locality, together with the various formations of the chalk, green sand, and galt, and the limestones and sandstones of the weald. This instructive region farther affords some striking proofs of that change in the relative level of the land and sea which we have

already named as characterizing this period of the history of the past, while some interesting circumstances of recent occurrence tend to prove that similar causes are in operation now. It is a well known fact, that an enterprise having been undertaken in the reign of James the First, under the direction of the celebrated Sir Hugh Middleton, for the purpose of draining Brading Haven, on the south-west side of the island, an attempt which was only abandoned, because the land proved to be so sandy and unfit for cultivation as not to repay the cost of reclaiming it, a well, cased with stone, was discovered near the middle of the haven, a fact which sufficiently indicated that the present bed of the waters was once dry land, and inhabited by mankind. Again; a very remarkable fact is mentioned by Sir Richard Worsley, in his History of the Isle of Wight, which serves to indicate an additional instance of change of level to a very considerable extent. He states,

" Looking eastward from the elevated spot, where the tower (on St. Catherine's hill) stands, two other hills are to be seen; the nearest, which is about three miles distant, is called Week Down, over which, about a mile and a half farther, appears that called Shanklin Down (or Dunnose Head). Concerning these downs a singular circumstance is remarked by the inhabitants of Chale, of which the evidence seems unobjectionable. Shanklin Down may now be guessed to stand about a hundred feet higher than the summit of Week Down, yet old persons, still living, affirm that within their remembrance Shanklin Down was hardly visible from St. Catherine's: they declare, moreover, that in their youth, old men have told them they knew the time when Shanklin Down could not be seen from Chale Down, but only from the top of the beacon, the old post of which

stands near the chapel. This testimony, if allowed, argues either a sinking of the intermediate down, or a rising of one of the other hills."

The phenomenon above described derives additional demonstration from the fact that the observations recently made in the mountains of the Andes by M. Boussingault, indicate that the various heights evince less degrees of altitude than those determined thirty years before by M. Humboldt, which tends to prove that a considerable submergence has taken place in the mountains of that continent during the same period of time; a fact which would also agree with the apparent elevation of the inferior limits of snow in that country. Castle Hill, near Newhaven, presents an epitome of the Hampshire basin, the cliffs revealing a succession of thin beds of the tertiary series, resting on a base of chalk, which forms the lower fifty feet of the cliff.

The Paris Basin.—Having thus briefly described the chief British localities in which the tertiary strata are developed, the basin of the Clyde; the crag of Norfolk and Suffolk; and the basins of London and of Hampshire and the Isle of Wight; we shall now cross the channel to inspect the more ample development of these formations on the wider area of the continent of Europe. It has been remarked, as a singular fact, that the two capitals of England and France are located on deposits of the same geological date and character; and Vienna, the site of which is found to be referable to the same formations, may be added to the list. The Paris basin extends over a larger area than the contemporaneous deposits of our own island, occupying a length from north-east to south-west, of about 180 miles, and a breadth, from east to west, of about 100. The strata presents a succession of beds which could

only have been produced by those alternations in the relative level of the land and sea, to which we have already referred.

The various deposits are thus classified, according to the most recent views formed on the subject.

1. Three formations of the same date, frequently alternating with each other, and resting on the foundation-chalk, consisting, 1st, of freshwater beds of plastic clay, containing lignite; 2nd, a marine limestone, the *calcaire grossier*; 3rd, a fresh water, siliceous limestone, the *calcaire silicieux*.

2. Marls and beds of gypsum, containing bones of quadrupeds, partly of the same date with the preceding, partly more modern.

3. Upper marine sands.

4. Upper fresh water marls with siliceous millstone.

The inferences derived from these varied deposits are in substance these:—It is conceived that an ancient gulf or depression of the chalk was filled by a sea of later date, which, extending on the north to the main ocean, was bounded on the south by a tract of land, the rivers of which brought down and deposited in its waters, the spoils of the country over which they flowed, the remains of animals and plants, and the shells of the river and the land, while mineral waters were occasionally infused into those of the sea. Changes took place in the relative level of land and water, producing fresh accumulations on the older deposits, and after extensive vicissitudes of this nature requiring a period of time correspondingly extensive for their development, the country rose to its present elevation. Events of like natuie, which we have already described as now in operation, afford an easy and natural explanation of these phenomena.

ORGANIC REMAINS OF THE PARIS BASIN.—Passing over the minor objects discovered in these deposits, the numerous shells, crustacea, and fish, and adverting, only for a moment, to the singularly perfect state in which so delicate a structure as that of birds is here discovered, their entire skeletons, and in numerous instances their very feathers being preserved, we will describe those remarkable animal forms which a Cuvier has brought to light, and with them revealed, as it were, a new science to the admiring world.

The gypsum quarries of Montmartre had long been known to afford fossil remains. Collections of these objects had been formed, and M. Guettard had figured and described many of the bones and teeth. But it was reserved for the illustrious Cuvier to complete the investigations thus commenced, and to effect discoveries which are not only invaluable in themselves, but have given a new impetus to scientific research, and incited others to pursue a career so auspiciously and successfully commenced. By following those principles to which we have already alluded, and which he had previously applied with success to the investigation of fossil elephants and mammoths, he formed an extensive collection, and having undertaken the apparently hopeless task of restoring order to these fragments and ruins, his intimate knowledge of the laws of structure enabled him to refer each bone, or portion of bone, to its approximate position in the osteology of the living animal, till their re-animated forms, as it were, lived and moved, and had their being before him. "The essential character of a tooth and its relation to the skull," he says, "being determined, immediately all the other elements of the fabric fell into their places, and

the vertebræ, ribs, bones of the legs, thighs, and feet, seemed to arrange themselves even without my bidding, and precisely in the manner which I had predicted."

The mode of induction followed by this distinguished observer in these researches was, in substance, that commencing, as he states, with the teeth, and comparing their structure with that of existing animals, he was enabled to infer their relation to living forms, and finding the characters of the bones to be perfectly in accordance with those indicated by the dental structure, he first completed the osteology, then invested the skeleton with those muscles which were predicted by the character and aspect of the separate bones; and lastly, clothing the whole fabric with the skin suitable to its general organization, the creature was restored to life.

The following group represents the chief animals which he thus revived.

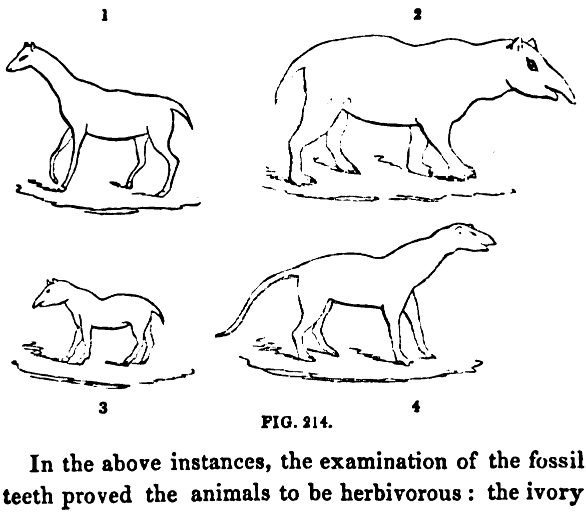


FIG. 214.

In the above instances, the examination of the fossil teeth proved the animals to be herbivorous: the ivory

and enamel being disposed in the alternate order previously described; while the characters presented by the crown of the tooth, which was composed of two or three single crescents, referred them to the *pachydermata*, certain genera of which present like forms of dentition, rather than to the ruminants, whose more minute mastication requires double crescents, each, with four lines of enamel. Pursuing these investigations, Cuvier at length established, that the greater portion of these remains belonged to two genera of *pachydermata*, bearing an affinity to the tapir, rhinoceros, and hippopotamus, creatures inhabiting marshes and rivers, in the mineralized beds of which these remains chiefly occur. Stuffed specimens of all these existing creatures are placed in the British Museum; the hippopotamus and rhinoceros occupying stations in the hall, and the tapir being placed beside the giraffes.

The animals figured above are divided into the following genera: *palæotherium*, an unmeaning name, signifying only an ancient wild beast; and *anoplotherium*, unarmed, so named from the absence of canine teeth, from *a* privative and οπλος armour.

Palæotherium magnum, fig. 2. This animal was as large as a horse, but thicker and more clumsy, with a massive head and short extremities. It resembled a large tapir, with differences in the teeth, and a toe less on the fore-feet. It was four or five feet high, and from the character of the nasal bones, must have possessed a short proboscis, or trunk.

Palæotherium minus, fig. 3, was a creature of the general character and appearance of the tapir, but with light and slender limbs, and was of the size of the roebuck.

Anoplotherium gracile, fig. 1, was of the size and form of a gazelle, and its character and habits must have resembled those of the deer or antelope.

Anoplotherium commune, fig. 4, was of the height of a wild boar, but more elongated in form, and having a long and thick tail, like the kangaroo; the feet having two large toes, like the ruminants. It is conceived to have possessed the power of swimming, and to have frequented the lakes, in the beds of which its bones are discovered.

Several other species of *carnivora* and *marsupialia*, a squirrel, a dormouse, and a bat have been discovered, as well as an animal allied to those just described, and named *anthracotherium*, from having been first found in the beds of lignite, or wood-coal, of Tuscany; this term, however, seems to require alteration, as remains of the animal have subsequently been discovered, in limestone marls, in Bavaria. Bones and teeth of the elephant, mastodon, hippopotamus, rhinoceros, and other mammalia also occur in these and other neighbouring deposits.

Tertiary Strata of Aix.—Other groups of tertiary strata occur in various parts of France. At Aix, in Provence, are beds of marls, and freshwater limestones, which have been so gradually and gently deposited by the waters which formed them, as to have preserved, in perfection, even the minute and fragile forms of insect life. In other portions of France and Switzerland, particularly at Œningen, the thinly laminated lacustrine marls have retained, in like perfection, objects of exceedingly delicate and fragile structure, as insects, birds, leaves, and stems of plants, together with crus-

tacea, fishes, turtles, salamanders, a tortoise, and the perfect skeleton of a fox.

STRATA AND ORGANIC REMAINS OF MONTE BOLCA.—This celebrated mountain, situated near Verona, about fifty miles from the lagunes of Venice, has long been a classic spot to the geologist, from the variety and profusion of the fossil fish entombed within its deposits. The strata are chiefly argillaceous and calcareous, with intercalations of a cream-coloured fissile limestone, which easily separates into laminæ, of moderate thickness, presenting fish in the most beautiful state of preservation, the only violence they have suffered consisting, in general, in their being squeezed flat; their bones, scales, fins, and the most delicate parts of the structure, being admirably conserved. From the volcanic character of the district, and the hill itself being capped with basalt, it is presumed that the limestone in which they are embedded was injected into the ocean, in a fluid state, by volcanic agency, and that the fish were thus suddenly destroyed: a result constantly observed in the occurrence of every marine volcano; it being obvious, that even a very slight adulteration of their native element renders it unfit for the respiration of fish, and thus terminates their existence.

DORMANT VOLCANOES OF CENTRAL FRANCE.—We now arrive at the description of one of the most splendid and striking features which characterize the vast history of nature during this peculiar period of her annals, the dormant volcanoes of the continent of Europe. Mr. Poulett Scrope, to whom we are indebted for an admirable account of this interesting region, and to whose excellent work we would refer for more ample particulars, remarks on the singularity of the fact, that the volcanic

phenomena of central France, its plains of lava, and hills of scoriæ and ashes, which so obviously bespeak their volcanic origin, should have remained so long unnoticed and unknown; and that, up to the last half century, no one should have thought of referring these phenomena to the only agency in nature capable of producing them. This apparent blindness, he adds, is, however, very natural, and is by no means without example. The inhabitants of Herculaneum and Pompeii built their houses with the lavas of Vesuvius, ploughed up its scoriæ and ashes, and gathered their chestnuts from its crater, without dreaming of their neighbourhood to a volcano which was to give the first notice of its existence by burying them under the products of its eruptions. The Catanians regarded as fables all relations of the former activity of Mount Etna, when, in 1669, half their town was overwhelmed by one of its currents of lava.

The circumstances under which public attention was called to these singular phenomena, are recorded in the following spirited manner by Mr. Poulett Scrope:— In the year 1751, two members of the Academy of Paris, Guettard, and Malesherbes, on their return from Italy, where they had visited Vesuvius, and observed its productions, passed through Montelimart, a small town on the left bank of the Rhone, and having walked out to explore the neighbourhood, the pavement of the streets immediately attracted their attention. It is formed of short articulations of basaltic columns, planted perpendicularly in the ground, and resembles, in consequence, those ancient roads in the vicinity of Rome, which are paved with polygonal slabs of lava. Upon inquiry they learned, that these stones were

brought from the rock upon which the castle of Rochemaure is built, on the opposite bank of the Rhone, and they were informed, moreover, that the mountains of the Vivarais abounded with similar rocks. This account determined the academicians to visit that province; and discovering every day fresh reason to believe in the volcanized nature of the mountains they traversed, they reached, step by step, the capital of Auvergne. Here all doubts on the subject ceased. The currents of lava, in the vicinity of Clermont, black and rugged as those of Vesuvius, descending uninterruptedly from conical hills of scoriæ, most of which present a regular crater, convinced them of the truth of their conjectures; and delighted with the information thus acquired, M. Guettard, on his return to Paris, published an account of the discovery. His statement, however, was heard with doubt by a public little prepared for scientific investigation, and a Professor of Clermont having published an essay, in which he declared these appearances to be nothing more than the remains of forges and iron-works, undertaken by the Romans, who, in all half-civilized countries, are considered to be the authors of every thing extraordinary or stupendous, the Professor gained more votaries than the naturalist, and the assertions of the philosopher were received with scepticism and distrust. The Professor should, however, rather have attributed these labours to the Gauls, the ancient inhabitants of Auvergne, who are mentioned by Cæsar as having possessed mines, and availed themselves of their skill, as miners, in the defence of the city of Avaricum.*

The attention of later observers having, however,

* Cæsar, lib. vii. c. 21.

been drawn to this region, and M. Desmaret having published his Memoirs on the origin of basalt, accompanied with maps of many of the lava-currents of Auvergne, all doubts were, at length, removed, and the true character of this singular region was fully and universally acknowledged.

The district which is the site of these volcanoes, is a vast plain, called *La Limagne d'Auvergne*, remarkable for its fertility, as is the case with all soils formed of volcanic detritus; it is inclosed, on the east and west, by two corresponding ranges of gneiss and granite; its average breadth being twenty miles, and its length between forty and fifty. The surface is formed of pebbles and boulders of granite and basalt, reposing on limestone; the river Allier flows through the district, over beds of this limestone, or siliceous sandstone, except where it has occasionally excavated a channel to the foundation-rock of granite. Hills composed of calcareous and alluvial deposits, which are scattered over the district, are conceived to be the relics of a more ancient plain, once existing at a higher elevation than the present, some of them being surmounted with basalt, others with limestone, which has protected and preserved them. On the western side of the plain the limestone disappears, and a plateau of granite rises 1600 feet above the valley of Clermont. This mass of granite supports a series of not less than seventy volcanic cones, varying in height from five hundred to a thousand feet, and forming a range nearly twenty miles in length, and two in breadth. The most remarkable of these ancient volcanic vents, are the Puy de Come and the Puy de Montgy.

For a description of these in detail, as well as of

the neighbouring volcanoes of the Vivarais, and the Cantal, we must refer to the admirable work of Mr. Scrope, and shall content ourselves with calling attention to one or two of the most remarkable features of so interesting a district.

It is the striking remark of a French philosopher in illustration of the power and benevolence of the Supreme Being; "*Si Dieu est grand dans les grandes choses, il l'est encore plus, dans celles qui sont petites.* If the Almighty is great in great things, he is still more so in those which are minute," and this singular region presents us with a striking instance of the power of the Supreme, as displayed alike in what we conceive to be the grandest operations of his will, and the meanest creatures of his hand!

Among all the vast and majestic agencies of nature, there is none comparable in sublimity and grandeur to that of volcanic action. A force which can melt up the solid materials of the earth, and by ejecting them as floods of lava over the surrounding districts can lay waste the most fertile regions of the earth; or by showering them as ashes to a distance, can overwhelm the fairest cities and entomb them for twenty centuries in the oblivion of the past; associated as its visitations frequently are with the fearful calamity of the earthquake, which spreads a like wide and devastating destruction—a force so terrific as this is, unquestionably, without a parallel in its magnificent but dreadful effects.*

* Allusion has already been made in the previous pages to the connexion between literature and science. The phenomenon here alluded to has given rise to perhaps the most perfect, as it is the most classical of modern fictions. Need we mention *The Last Days of Pompeii?*

This tremendous power is, as we have seen, most extensively developed in this singular region. When we contemplate not a single volcanic vent, not a solitary Vesuvius, an Etna, or a Hecla, but numbers of these comprised in a single district, we are compelled to recognise the vast and stupendous scale on which this fearful agency was exerted, at a period, the phenomena of which are unparalleled, not only at the present day, but during the whole history of the past. Having thus briefly pointed out the power of the Deity, exemplified on a scale of infinite majesty and grandeur, as regards the mightier manifestations of his power, we shall now call attention to the same attributes, as evinced in relation to objects conceived to be among the most minute and insignificant in creation.

There is a little creature of the order of *crustacea*, some species of which inhabit our ponds and ditches, the body of the animal residing within its two cases, like the mollusc within the valves of a bivalve shell,

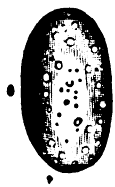


FIG. 215.

its principal organs of motion consisting of its *antennæ*, or feelers, which protrude from between the valves, their terminations being furnished with cilia, or slender pencils of hair. These shields, or coverings, it throws away every year, and we may judge to how great an extent,

and during how incalculably long a period, these creatures have continued to cast their coverings in the quiet waters of the lake, when we learn that beds of limestone, one hundred feet in thickness, are, in an essential degree, formed of the rejected coverings of these animals, which divide the limestone into laminæ, no thicker than the leaves of a book.

Other beds are composed in a manner still more striking, and calculated yet more strongly to display the power of the Supreme, as regards the most apparently trivial of his creatures. There is an insect, called the *phryganea*, or may-fly, which, in its larva state, is called the caddis-worm, and is then employed by the angler in his cruel sport for the purpose of bait, and which possesses the following remarkable instinct as described by Kirby and Spence, in their valuable treatise on entomology. "Not having the power of swimming, but only of walking at the bottom of the water, by means of the six legs attached to the fore part of the body, which is usually protruded out of the case, and the insect itself being heavier than water, it is of great importance that its house should be of a specific gravity, so nearly that of the element in which it resides, as while walking neither to incommode it by its weight, nor by its too great buoyancy; and it is as essential that it should be so *ballasted* in every part as to be readily movable in any position. Under these circumstances our caddis-worms evince their proficiency in hydrostatics, selecting the most suitable substances, and if the cell be too heavy, gluing to it bits of leaf or straw; or, if too light, shells or pieces of gravel." The accompanying illustration depicts a case

of this kind in the possession of the author, in which the attached objects are a minute species of *paludina*, a fresh-water shell.

FIG. 216.

In a similar manner, a large and extinct species of caddis-worm, which abounded in the ancient lakes of Auvergne, was accustomed to cover its case with the shells of a small species of the univalve genus *paludina*. Vast beds of the limestone of this region are essentially composed of these objects in a fossil state, and are termed indusial limestone, from the Latin *indusium*, a case. When, as Mr. Scrope observes, we consider that ten or twelve of these cases may be packed within the space of a cubic inch, and that some single beds of this limestone may be traced over an area several miles in extent, we may form some idea of the countless numbers of insects and molluscs, whose remains have contributed to form this remarkably constituted rock; while we can but be struck with the incalculable period required for its deposition, and the cycles of ages during which the tranquil waters of the lakes must have continued to deposit these singular sediments.

Yet these indusial limestones form but a portion of the strata of the district, and the period of the lakes, however protracted, constitutes but a part of the changes indicated by the phenomena of the region. The va-

rious beds present a series of alternate volcanic and lacustrine deposits, an accumulation of clays, sands, breccias, beds of gypsum, and freshwater limestone, containing organic remains, both lacustrine and terrestrial, the spoils both of the lake and the land, with intrusions of volcanic matter, consisting of lavas, scoriæ, and basalts, to so enormous an extent, as to indicate no less than six successive eras of alternate activity and repose, each of vast duration, and tending, in the aggregate, immensely to increase the geological antiquity of these formations, and consequently of the earth itself.

The beds of freshwater limestone contain, in addition to vegetable remains, and land and freshwater shells, teeth and bones of the *palæotherium*, *anoplotherium*, deer, ox, martin, dog, &c.; while the overlying deposits of sand and diluvial gravel imbed teeth and bones of the elephant, mastodon, hippopotamus, rhinoceros, tapir, horse, deer, ox, boar, hyena, bear, felis, dog, castor, hare, &c.

The Abbé Croizet, some years since, formed an extensive collection of the fossils of this interesting district, which was purchased by the French Government; and pursuing the same researches he has succeeded in forming a second assemblage of similar objects.

General Character of the Country and its Inhabitants.—We have already had occasion to observe that the character and history of an entire community are identified with their geological site and position, a fact which has been strikingly exemplified in the annals of the natives of Auvergne. They, like all mountaineers, and inhabitants of difficult and inaccessible countries, have ever proved themselves brave and

patriotic. Primitive in their habits, and faithful to their native soil and its institutions, they have offered a resistance to the invader which was the more vigorous from the advantages afforded by the inaccessible nature of the region. Their gallant chief, Vercingetorix, arrested a Cæsar in his career of victory, and in a memorable battle defeated the Romans, with the loss of Lucius Fabius, Marcus Petreius, forty-four other centurions, and seven hundred soldiers.* In modern times, the feudal barons of the province, secure in the castles erected on the volcanic peaks of this singular region, long defied the sovereign power, and called forth all the policy of a Richelieu, and the energy of a Louis XIV., to reduce them within the rule of established authority.

Erosive Force of Streams.—The power of running water to erode the solid rocks, and to produce valleys by their currents, is most strikingly exemplified throughout the whole of this remarkable district. It is to be observed, that the erosive power of water has been aided by the proneness of the volcanic rocks to decompose. In some instances beds of lava have been corroded by waters which have worn through a mass of rock 150 feet in height, and have formed a channel even in the granite beneath, since the lava first flowed into the valley. In another spot, a bed of basalt 160 feet high has been cut through by a mountain-stream. In the valley of Monpezat, the mass of basalt has been similarly worn in more than one direction, by the powerful action of the rivers whose channels it had usurped; its present disposition and the beautiful columnar ranges discovered by this excavation, may be judged by the following delineation, which is copied from the admirable work of Mr. Scrope.

* Cæsar, lib. vii. c. 48.

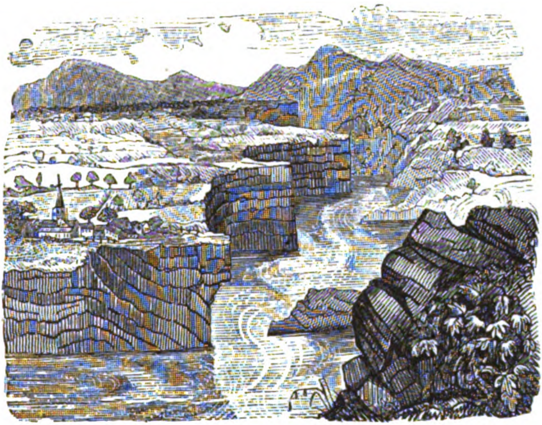


FIG. 217.

DORMANT VOLCANOES OF THE RHINE.—The beautiful banks of the Rhine—the classic haunts of the tourist and the poet, the theme of a Byron and a Bulwer, are of course indebted, like every other region of the earth, to their geological condition for the advantages they enjoy. To their volcanic character and origin the scenery of this lovely land is indebted for its unrivalled beauty, and its celebrated wines for their flavour and their fame. "The castled-crag of Drachenfels," with the remainder of the Siebengebirge, or seven mountains, and the Eifel, on the opposite side, with every castellated summit throughout the entire region, from Bonn to Mayence, are so many piles of volcanic rock, the decomposition of which constitutes a rich and luxuriant soil, forming a very hotbed for the cultivation of the grape. The geological structure of the district differs from that of Auvergne in the circumstance that

the foundation-rocks are identical with those of the Silurian system of Mr. Murchison, consisting chiefly of coarse red sandstones and slate of peculiar kinds. Through these strata trachyte and basalt have forced their way, the trachyte being loose and liable to decompose, and though much employed for building, proving a faulty and decomposing material. The cathedral of Cologne is built of the trachytic rock of the Drachenfels : it is, however, found so defective, that the additions to the edifice are executed with a more durable stone. The basalt is black, and frequently columnar; the columns are used for pillars, posts, and paving. The walls of the town of Lintz, Mr. Horner informs us, are constructed of these materials : such, in short, is the profusion of volcanic rocks that they are applied to the meanest and most common purposes; and the writer remembers, while gliding in the steam-boat past the quay at Düsseldorf, to have seen pillars of basalt lying carelessly strewed upon the wharf, each of which would have been a prize to a public collection. The foundation-rocks are overlaid by a series of tertiary deposits, consisting of beds of sand, sandstone, clay, and lignite, forming what is termed the brown-coal formation. Over these beds are spread extensive layers of gravel, which are covered by a loosely-coherent sandy loam, provincially termed *loess*, containing recent species of land and fresh-water shells. Mr. Lyell, in his admirable Principles of Geology,* has treated at length of these deposits, and infers, as a general conclusion, that though the *loess* has been deposited since the existing system of the hills and valleys has prevailed, yet that import-

* Vol. iv. p. 33, and sequel.

ant changes have taken place in the physical geography of the country since its deposition, and that all the land between Switzerland and Holland has undergone a subsidence and a subsequent elevation of many hundred feet.

TERTIARY STRATA OF OTHER REGIONS.—Similar dormant volcanoes exist in Hungary, Spain, and other parts of Europe, and the celebrated salt mines of Gallicia, are referred by M. Boué to the tertiary epoch. Strata of the same geological date also occur in North and South America, where, in the Cordilleras mountains, Mr. Darwin has effected the farther discovery that granite has been fluid so late as the tertiary period. They exist in the Himalayah hills, and in Australia, and the latest accession to our knowledge of deposits of this character consists of the discovery by M. Boué, which has been confirmed by our countrymen, Messrs. Hamilton and Strickland, of a district in Asia Minor, in the vicinity of Smyrna, called the Κατακεκαυμενη, or Burnt-up region, comprising the ancient Sardis and Philadelphia, which presents a very close resemblance to the volcanic tract of Auvergne. In each country are extensive lacustrine formations, cones of scoriæ, with currents of lava, and occasionally continuous streams and thick beds of that substance, worn through by the action of running water. The Rev. Mr. Russell, a missionary to Madagascar, has informed the author that the interior of that island presents phenomena of similar nature.

FOSSIL INFUSORIA.—We have already alluded to the researches of Professor Ehrenberg, on the subject of the recent *infusoria*, and it is in strata of this formation that he has effected the striking discovery that a certain

kind of siliceous stone, called Tripoli, from the place in Africa where it occurs, and which is also found at Bilin, in Bohemia, and elsewhere, is entirely composed of the skeletons, or cases of microscopic animalcules. They consist chiefly of a species of *gaillonella*, the *g. distans*, and it is a well known circumstance that Ehrenberg ascertained them to be of such excessive minuteness, that every cubic inch of the substance contains 41,000 millions of the mineralized skeletons of these microscopic beings. It is a fact, however, not so generally known, that these remains are absolutely gigantic when compared with those of another species of the same genus. The well known substance, called bog-iron ore, or *gelberde*, the Professor has ascertained to be similarly composed of the thread-like cases of animalcules so inconceivably minute, the *gaillonella ferruginea*, that every cubic inch contains no less than two millions of millions of these once living and highly organized forms; in other words, more than two million times the number of the whole human race now existing over the entire face of the earth. Such is creation!—what then the Creator?

The same strata, at Bilin, also presents a bed of semi-opal, which contains portions of animalculæ, with the spicula, or internal siliceous supports of the *spongilla*, or freshwater sponge. The rock is conceived to have been formed by the decomposition of shells which have preserved and imbedded the siliceous fossils.* Professor Ehrenberg has also recently discovered, in the tertiary deposit of Eger, in Bohemia, a stratum two miles long, and twenty eight feet thick, composed

* See the *Infusionsthierchen*, p. 170, art. *Gail. distans*.

almost entirely of fossil animalcules. More recently Professor Rogers, an American *savant*, has ascertained that a bed of older date than those in which similar remains have hitherto been detected, a stratum interposed between the eocene and miocene deposits, extending over a considerable area, the city of Richmond, in Virginia, being built on its site, and twenty-eight feet in thickness, is composed of fossil infusoria, chiefly of the genera *navicula* and *gaillonella*.

The remarkable composition of these singularly constituted rocks, be it observed, tends strongly to confirm the supposition of the organic origin of the calcareous deposits, which is now so generally entertained.

Conclusion.—We have thus brought to a close our remarks on this interesting and instructive period of the history of nature. Our observations, however inadequate as compared with the themes which it is our purpose to describe, are more ample and extensive than those which we shall devote to either of the remaining formations, for the obvious reason that, as many of the phenomena of nature observable in the tertiary rocks are repeated in the older deposits, the explanation of these, in the first instance, will remove the necessity of their repetition in succeeding cases. The foregoing remarks, however, it is presumed have sufficed to prove those characteristic facts, which it is peculiarly the object of the beginner to acquire, and which were expressly stated at the commencement of the present chapter.

Thus the deposition of the tertiary strata in depressions of the chalk and the older rocks, is demonstrated by the basins of London, of Hampshire, and the Isle of Wight, and of Paris; the changes in the level of land and sea are alike proved by the alternations

of freshwater and marine strata in the two last-named of these deposits, as well as in the phenomena of the well discovered in Brading Haven, and the presumed depression of Week Down: the existence of extensive lakes is shown by the lacustrine formations of the continent of Europe: the development of volcanic agency is equally evident from the physical geography of Auvergne and the district of the Rhine; while the refrigeration of the climate is similarly testified by the change in the forms both of animal and vegetable existence; in the one instance by the disappearance of colossal reptiles, the earliest prevalence of mammalia, and the approximation of the shells to living forms; and, in the other, by the like gradual introduction of existing plants, and the more European character of the climate and its productions.

EXERCISES

ON THE TERTIARY SYSTEM OF DEPOSITS.

1. Explain the meaning of the term tertiary.
2. Describe the geographical distribution of the strata appertaining to these formations.
3. Name the chief authors and the principal collections of organic remains.
4. Describe the characteristic features of these deposits.
5. Repeat the classification proposed by Mr. Lyell, the names of the divisions, and the relative proportions of shells identical with existing forms which determine them.

6. Name the most important localities of these beds in this country.

7. Mention the principal characteristic shells of the crag, and London basin.

8. Describe the basin of Paris, its extent, and distinctive organic remains.

9. Name the chief features of the geology of Auvergne, its physical geography, alternation of deposits, fossil remains, and the changes and revolutions inferred from its varied phenomena.

10. Mention the remaining deposits of this age and nature occurring in France.

11. Name the fossil productions of Monte Bolca.

12. Describe the physical geography of the banks of the Rhine, the alternations of strata, and the changes and revolutions thus indicated.

13. Name the localities in which similar phenomena are observed in Europe.

14. Mention the latest discoveries effected with reference to this period of nature's history in other parts of the globe.

CHAPTER XI.

THE CHALK FORMATION.

CHALK, CRAIE OF FRENCH; KREIDE OF GERMAN AUTHORS; CHALK-MARL, ENGLISH: CRAIE-TUFAU, FRENCH: KREIDE MERGEL, GERMAN: GREEN-SAND, ENGLISH; GLAUCONIE-CRAYEUSE-SABLEUSE, FRENCH; CHLORITISCHE KREIDE, GRUENER SAND, GERMAN.

MUSEUMS:—GEOLOGICAL SOCIETY, COLLECTION OF DR. MANTELL IN THE BRITISH MUSEUM; THAT OF MR. BOWERBANK, MR. SAULL, MR. DIXON, OF WORTHING, MR. PURDUE, AND MANY PRIVATE COLLECTIONS IN THE SOUTHERN AND EASTERN COUNTIES, YORKSHIRE, &c. &c.

AUTHORS:—MANTELL, LYELL, PHILLIPS, WOODWARD, BOBLAYE, VIRLET, &c. &c.

CHARACTERISTICS:—FIRST OF THE SECONDARY FORMATIONS; MARINE; THE BED OF AN ANCIENT SEA, CONTAINING THE USUAL MARINE FOSSILS, WEEDS, PLANTS, CORALS, SHELLS, FISH, AND REPTILES.

It is the admirable remark of Lavater, that we cannot pick up a pebble by the way-side, but we find all nature in connexion with it; and thus a substance so common and familiar as a piece of chalk proves, on investigation, to be connected, in an intimate degree, with the physical history of our earth. The chalk constitutes the boundary of the secondary system of deposits; it is the bed of a primeval ocean, of enormous area and extent, and it is from the spoils of this formation that our existing islands and continents are largely composed.

Subdivision of the Chalk Formation.—The deposits of the chalk are arranged under four principal

divisions, the first only of which is represented by the pure white limestone, which is so familiar to us as chalk. This chalk is again subdivided into two members, the upper, or flinty chalk, and the lower, which is usually destitute of flints. It is generally white, but, in some districts, red, yellow, grey, or nearly black. The second division is the marl, a clayey limestone, which universally prevails beneath the white chalk; it occasionally contains a considerable admixture of green sand, when it is called glauconite, or firestone, being employed in the construction of ovens, from its power of resisting heat. The third is the galt, a provincial term, denoting a stiff, blue or black clay, abounding in shells, which frequently possess a bright metallic lustre; while the fourth consists of the green sand, which is divided into upper and lower, the lower division being of dark, ferruginous aspect, and separated from the upper by beds of clay. As strata appertaining to the green-sand formation are largely developed in various parts of the continent, particularly in the neighbourhood of Neufchâtel, the French geologists have raised these deposits to an independent rank, under the title of the *Systême Néocomien*, from the name of that town; assuming that these beds constitute the marine equivalent of the wealden formation. The fossils are the same as to genus, but differ in species from those of the green-sand. Mr. Austen has detected beds of this character, and containing similar fossils, both in Surrey, Kent, and the Isle of Wight, but as these unquestionably belong to the green-sand, it results that the hypothesis which would render these strata, as they exist on the continent, the equivalent of the wealden

formation must be abandoned, and, in all probability, they will eventually be found to be no other than that larger development of a peculiar deposit, which is a circumstance of very frequent geological occurrence.

The fossils of the entire series are essentially the same, though presenting local varieties of genus and species. They consist of marine plants, sponges, corals, echinites, belemnites, ammonites, fishes, reptiles, and other marine exuviæ, with occasional instances of wood and plants drifted from the land, the whole presenting forms of life specifically distinct from those occurring in the overlying beds; no species discovered in the chalk being identical with those of the tertiary deposits above. They evidently form the spoils of a primeval sea, which rivalled in extent the mighty oceans of the southern hemisphere at the present day; the chalk deposits extending over portions of the British islands, various parts of France, Germany, Denmark, Sweden, Russia, and North America.

Origin of the Chalk and Flint.—The idea which prevailed, up to a very recent period, as to the origin of these objects was, in substance, this:—It was conceived that streams, probably of thermal, that is, of hot waters; but, at all events, such as were charged both with calcareous and siliceous matter, with particles both of lime and flint, were poured into the then existing ocean, and that, on mingling with the colder waters of that sea, both the calcareous and siliceous substances were precipitated in a solid state, and separating by the laws of chemical affinity, deposited the chalk and flint of this formation. The experiment may be partially realized by the student with the aid of any easily crystal-

lizable salt; for instance, if a small portion of powdered alum be placed in a cup of hot water over night, it will be found precipitated in a solid state in the morning.

It is well-known, however, that many distinguished observers had been induced to ascribe these substances to a different cause. It is now a century since Linnæus, as we have before observed, declared his conviction that the calcareous strata are of animal origin, and the recent observations of microscopic observers have tended amply to confirm the conclusion of this greatest of observers. Not only has Mr. Lonsdale discovered that the chalk, when reduced to powder, and appearing like mere grains of dust to the eye, consists, in fact, of well-preserved fossils of the beautiful forms depicted by Mr. Lyell, in his Elements; but the distinguished Ehrenberg has ascertained that these specimens are really gigantic, when compared with the smaller forms of life which are contained within them, and that the chambers and apertures of these *foraminifera* are filled with thousands of well-preserved infusoria, and other animalcular creatures, whose skeletons abound in every grain of chalk.

In fact, we have only to grate a piece of chalk in water, and dry the particles thus obtained, and we shall find, on submitting them to the microscope, that instead of the mere shapeless grains which they appear to the unassisted sight, they present evident marks of structure, and are, in short, microscopic shells, or corals, or portions of these, all exhibiting indisputable proofs of organic origin.

As many of the other rocks are found on microscopic inspection to present similar appearances, it is con-

sidered that not only is the chalk of organic derivation, but that a large proportion of the sedimentary rocks, from the tertiary beds to the lowest fossiliferous deposits, are all derived from the same sources, and have all passed through the great laboratory of life. This opinion of the vital origin of the calcareous strata derives considerable confirmation from the operations of nature at the present day. Not only is it found that the coral insect is rearing its reefs and islands from the bosom of the deep, and uniting them into continents, but it is observed on the shores of many of the West India Islands, especially the Bermudas, that the coral formations being exposed to the abrading power of the waves, the sea becomes loaded with calcareous matter, a considerable portion of which is wafted to the shores in the state of fine sand, which, being drifted inland by the winds, becomes consolidated by the percolation of water, and the infiltration of crystallized carbonate of lime; so that a white calcareous stone is formed, of various degrees of hardness, from coarse friable limestone, to the compact stone employed in constructing the fortifications of the island, but still including corals and shells, even in its firmest and hardest form.

Lieutenant Nelson, in a highly valuable memoir on the geological formation of the Bermudas, states, that the whole of these islands, comprising a hundred and fifty in number, and perhaps many of the older rocks, as well, may be called organic formations, as they present but one mass of animal remains, in various stages of comminution and disintegration. From the most compact rock to the very sand of the shore, the materials are universally fragments of shells, corals, &c. In

another part of the memoir he ascribes the Bermuda chalk to animal origin, and suggests the extreme probability, that the chalk of Europe was produced by similar causes, since their external and chemical peculiarities are as much the same as their common character of being marine deposits.*

The celebrated human skeleton, of Guadaloupe, at present in the British Museum, has been already mentioned as being embedded in a limestone of the same modern character; and it is scarcely possible to conceive a more perfect analogy than is here presented, between the operations of nature at the present moment, and those exhibited in the primeval æras of her history. A striking demonstration is thus afforded of the efficacy of modern causes, a principle so admirably enforced by Mr. Lyell, in his larger work, by which that distinguished observer triumphantly proves the harmony of nature with herself, and shows that the chief mutations, and most striking phenomena which have occurred in the history of our earth, have been occasioned by causes analogous to those which are effecting similar changes, and producing corresponding results at the present day.

ORGANIC NATURE OF FLINT.—While the vital origin of the chalk, and the calcareous deposits, is thus conceived to be established, the attention of microscopic observers has been directed to the flint, and the noble President of the Royal Society, the Marquis of Northampton, has discovered in flints from the chalk a minute univalve shell, allied to *spirula*, which his lord-

* See Trans. Geo. Society, vol. v. p. 115.

ship has therefore termed *spirolinites.* The Rev. Mr. Reade has ascertained the presence in similar objects of organic substances, still more fragile and minute, such as the scales of fish, and even the cartilaginous support of the scale; while Mr. Bowerbank, by a series of microscopic observations, has arrived at the conclusions which he has stated in a memoir, read before the Geological Society,* which are in effect that both the tabular and nodular masses of flint are due to sponges, and that the flints which fill up the cavities of shells and echini are owing to a similar cause; in other terms, that every flint of the chalk, whether of a tabular or nodular form; or filling up a shell or an echinus; was once a sponge, which either grew in an independent position, or occupied cavities of the shells or echini in a manner analogous to that in which sponges are known to invest similar substances at the present day.

Fossils of the Chalk.—These are extremely numerous and are entirely marine, consisting of sponges, corals, zoophytes, echini, shells, crustacea, fish, and reptiles. It may be considered as a strong confirmation of the views entertained by Mr. Bowerbank, that the flints of this deposit are so constantly associated with organic substances that it is scarcely possible to meet with a flint from the chalk which does not contain a sponge, zoophyte, or shell, or the impression of these objects. The following form of flint, which is by no means of uncommon occurrence, is owing to the silicification of a zoophyte, described by Dr. Mantell as a *ventriculite.*

* See Transactions, vol. vi., p. 181.

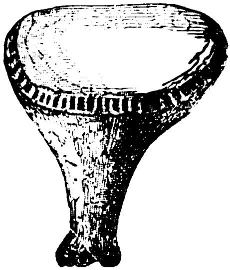


FIG. 218.—Ventriculite silicified.

The markings round the rim occasionally present a very striking appearance, and I am indebted to a friend for the fact, that a flint of this kind having fallen into the possession of a virtuoso, was transmitted to the Society of Antiquaries, for the purpose of deciphering the supposed inscription, when it was ascertained, but not till after considerable deliberation, that the characters were inscribed by the hand of nature, and not by that of man.

The corals are comparatively few, and chiefly of the smaller kinds, the madrepores and large stony species are absent, a fact which tends to prove, with other evidence, that the chalk was deposited in the abysses of a profound ocean, the nature of the larger species allowing them to exist only at moderate depths. Fossil zoophytes, of forms and characters peculiar to this formation, the choanite, marsupite, &c., have been discovered and figured by Dr. Mantell in his various works. The latter he states to have borne much resemblance to the *crinoidea*, differing however in the fact that it was destitute of a stem, or of any radical processes of attachment. It was a molluscous animal, having a central mouth, surrounded by *tentacula* or arms. The skeleton consisted of crustaceous, hexagonal plates, the arms of

numerous *ossicula*, or little bones. The creature doubtless had the power of spreading out these arms to seize its prey, and then of closing and conveying it to the mouth.

FIG. 219.—The marsupite.

The family of the *echinodermata* are extremely abundant, and the accompanying illustration depicts some of the most familiar of their forms.

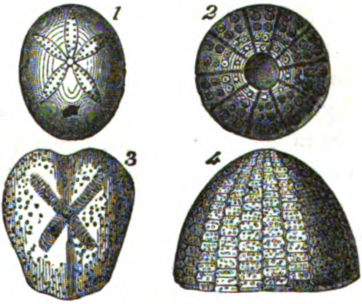


FIG. 220.—1. Nucleolites. 2. Cidaris diadema. 3. Spatangus cor-anguinum. 4. Ananchytes ovatus.

I am indebted to the kindness of J. Purdue, Esq., for a drawing of the following rare and beautiful species of *cidaris*, or turban-shaped echinus, collected by him from the Kentish chalk.

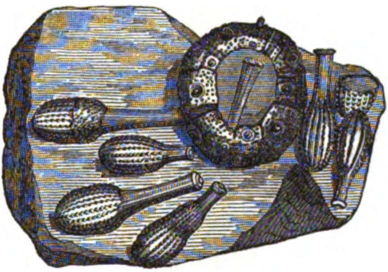


FIG. 221.—Cidaris margaritifera.

SHELLS OF THE CHALK.—The accompanying figures represent several of the most usual shells of this deposit.

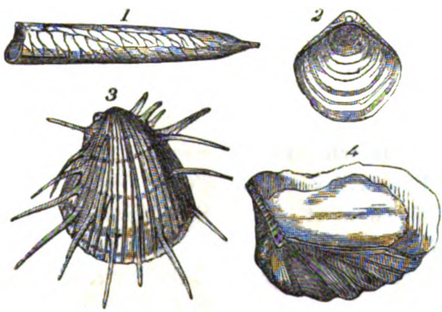


FIG. 222.—1. Belemonites Listeri. 2. Terebratula carnea. 3. Plagiostoma spinosom. 4. Catillus (Inoceramus) Cuvieri.

Of the above, the *catillus*, also called the *inoceramus*, is a shell of thin and fibrous structure, and on this account is rarely found in an entire or perfect state; the *spondylus*, also termed *plagiostoma*, is analogous to the thorny oyster, existing only in tropical seas at this moment; the *terebratula* is a well-known shell, which, originating in the earliest formations, and being profusely distributed through the succeeding deposits, has dwindled down to two or three species at the present day; while the *belemnite* was an internal bone or shell analogous to that of the *sepia*, or cuttle-fish, whose skeleton is also internal. The living animal, it is well known, has the power of secreting a dark-coloured fluid or ink, which, when pursued by an enemy, it ejects into the water and escapes by favour of the darkness which it thus creates. This ink, which is contained in a bag, forms, when prepared, the sepia of the artist and enters into the composition of Indian ink. The *belemnite* has been discovered with the external sheath, the conical, chambered shell, the ink-bag and bone; the ink though fossilized retaining its power so strongly, that having been prepared for use, it was employed by one of our most celebrated artists; and figures of the fossil creatures have actually been drawn with the sepia furnished from their own mineralized remains.

Shells of the subordinate Members of the Chalk Formation.—The following figures exemplify several of the most characteristic fossils of those deposits which underlie the upper strata of the chalk,—the marl, galt, and green-sand. With reference to the galt, it may be observed that advantage is frequently taken of the soft nature of the substance, to mould it into round nodules, and to imbed in the masses

so formed, the characteristic shells of the formation.

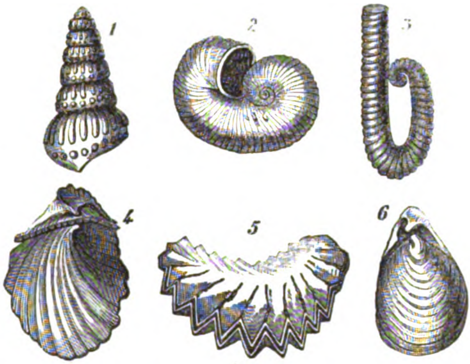


FIG. 223.—1. Turrilites costatus, (Chalk Marl.) 2. Scaphites striatus, (Marl. 3. Hamites, (Marl.) 4. Catillus or Inoceramus sulcatus, (Galt.) 5. Ostrea carinata, (Green Sand.) 6. Catillus, or Inoceramus concentricus.

The remains of asteriades, or star-fish, and of crustacea (chiefly crabs) of extinct forms allied to tropical genera have been discovered: teeth of sharks also constantly occur in a perfect and beautiful state of preservation.

Fishes of the Chalk.—But the most important and interesting remains, exhumed by Dr. Mantell from this formation, consist of the numerous and admirably preserved fishes which he has extracted from their sepulchres of the chalk. The history of the researches and discoveries of this distinguished observer in this, and an adjacent district of the same county, Sussex, both of which he has, by his persevering and successful labours, rendered classic ground to the geologist, would more than occupy the space allotted, in an elementary work, to the entire description of the whole formation. Suffice

it to mention, that naturally conceiving that a sea could not be destitute of fish, Dr. Mantell, by stimulating the labourers in the quarries adjacent to his place of residence, and assisting their researches by his personal superintendence and exertions, succeeded, after many years of toil and research, in forming a collection of the fossil fish of these deposits, which, having constituted the admiration of individual *savans*, and furnished the materials for an entire portion of the work of Professor Agassiz on Fossil Fishes, has been deemed worthy of acquisition by the nation, has consequently been purchased by the Trustees of the British Museum and now forms a part of the National Collection.*

Various specimens of these interesting objects are figured in Dr. Mantell's Wonders of Geology, and we shall only select the celebrated specimen of *Osmeroides Mantellii* as the close of our observations on these singular remains.

The fish here depicted is remarkable for presenting all the attributes of animation, and is perhaps, of all fossil objects, that which is nearest allied to life. The mouth is open, the gills are expanded, the fins are extended, while the body is uncompressed, proving that the air-bladder was inflated; phenomena which show that the creature must have been living, moving, breath-

* The following is the eulogy of Agassiz on this highly interesting collection:—"Tout le monde sait que le Musée de M. le Dr. Mantell est une collection classique pour la craie et la formation Veldienne. Les soins minutieux que M. Mantell a donné, depuis bien des années, à ces fossiles, les ont rendus plus parfaits que tous ceux des autres musées; car, souvent il est parvenu à les détacher, entièrement, de la roche dans laquelle ils se trouvaient; ou du moins, à les produire en relief, en détachant toutes les matières solides qui recouvraient les parties les mieux conservées de l'animal."

ing when it was surrounded by the chalk, which, having been reduced to a fluid state by some agency (possibly volcanic) first choked the animal, and then by hardening and indurating round it, preserved it in its fossil state.

FIG. 224.—Osmeroides Mantellii.

It may here be mentioned that F. Dixon, Esq., of Worthing, has formed a very splendid collection of the fossils of the chalk, comprising many rare and unique specimens, among which are examples of the *hippurites* and *sphærulites*, which though not unfrequent in the cretaceous beds of the Pyrenees, and other parts of the continent, are most rare and uncommon in the English chalk. They will be figured and described in a forthcoming publication by this gentleman on the zoology of the chalk formation.

THE MOSOSAURUS.—The chalk of Kent and Sussex have likewise afforded teeth and vertebræ of the mososaurus, or lizard of the Meuse, a creature which excited very considerable interest at the period of its discovery, though its fame has since been eclipsed, by the more colossal and splendid animal remains of the same

class, brought to light by Dr. Mantell, and other recent inquirers. It was a marine lizard, pronounced by Cuvier to have been intermediate between the monitor and iguana; it is conceived to have been twenty-five feet in length, and to have possessed a tail which, at some distance from the body, became flat like an oar, and formed a powerful instrument of propulsion. The circumstances connected with its history, as related by M. Faujas de St. Fond, in his work on the subject, are of considerable interest. It was discovered in the strata of St. Peter's Mountain, at Maestricht, which are conceived to be of a character intermediate between the tertiary deposits and the chalk. It was first brought to light by the celebrated Hoffman, and, after six weeks of anxiety and toil, was extricated from its rocky tomb, and borne by the philosopher in triumph to his house. The ground, however, in which it was discovered proving to be part of the cathedral domain, the canon of that establishment succeeded, after a tedious law-suit, in establishing his right to the relic, and thus snatched his prize from the philosopher, who went to his grave regretting the loss. The events consequent on the French revolution brought a French army to the gates of Maestricht, and with it a committee of *savans*, appointed to secure possession of the specimen on the capture of the city. A flag of truce was accordingly despatched to the garrison, requesting that a signal might be hoisted on the town-hall, in which it was known to be deposited, with the view that no shot or shells should be fired in that direction. On the capitulation of the city, the philosophers hastened to the spot; but the treasure was flown; the promise, however, of a reward, consisting of some hundred bottles of the excellent wine of

the district, soon stimulated the French grenadiers to discover the object, and it was brought to the committee, who were anxiously waiting to receive it. If the zeal felt by the French amid the excitement of a revolutionary war, to secure and preserve an object of scientific interest, appear deserving of commendation; we can still less withhold our admiration of the feeling which induced them to seek out the family of the deceased philosopher, and pay to them what was deemed a fair compensation for the object. The relic itself having been received in commutation of a requisition levied on the captured city, was transported to Paris, where models of it were made under the superintendence of Cuvier, one of which, a present from Cuvier to Mantell, is now in the British Museum.

Mr. Mackeson, of Hythe, has recently discovered in the green-sand of that vicinity, the remains of a reptile of colossal size, now deposited in the British Museum, which, from the teeth exhibiting peculiar fold-like markings, Professor Owen has described under the name of the *polyptychodon.**

DENUDATION OF THE CHALK.—This brief epitome of the cretaceous deposits may be appropriately closed by an account of the denudation of the chalk, as it is usually termed; that is, its removal from the valleys of the weald, which lie between the ranges of the north and south downs. The former present a range of chalk hills, which have a steep escarpment towards the south, and extend from Godalming, through Godstone, into Kent, terminating in the cliffs of Dovor. The latter are a similar series of elevations, which have a corresponding escarpment towards the north, and from

* See Proceedings of the Geological Society, part iii. p. 449.

the promontory of Beachy Head, traverse the county of Sussex east and west, and pass by Hampshire into Surrey.

At the base of each of these escarpments, the upper green-sand, and sometimes the galt, are first found to crop out, and we next reach the valleys of the weald. The chief proofs of the denudation or removal of the chalk, consist in the appearance of the strata in each of these escarpments. They terminate sharply, and it is evident must once have extended much farther, since they offer precisely such appearances as would be presented by the cutting off, in an abrupt manner, of strata which were previously continuous. Proofs no less conclusive are afforded by the conformation of the wealden beds themselves, since they present, in the elevation called the forest-ridge, which traverses the district in a direction nearly east and west, a perfect anticlinal axis, from which the strata diverge on each side towards the chalk-downs, affording the most convincing proofs of the elevation of these wealden deposits, and the consequent destruction and removal of the chalk and other beds, which may have been deposited upon them. It is farther conceived, that the tertiary strata which overlie the chalk in the vicinity of the metropolis once extended, in like manner, over the chalk which reposed on the weald, and covered with their deposits the whole area of the south-east of England. This supposition, which is highly probable in itself, receives very powerful confirmation from the relics and outliers of the tertiary formations, which occur at Castle Hill, Newhaven, and near Seaford.

In reviewing the characters of the chalk formation, we shall find them to exemplify those features which

we were desirous, at the commencement of this sketch, to impress on the attention of the beginner. We have evidence that these varied strata are the mineralized bed of a vast and extensive ocean, which rivalled in grandeur and expanse those which prevail in the southern hemisphere at the present day. It abounded in the usual forms of marine organic existence, and the fossil remains of its former inhabitants are sea-weeds, sponges, corals, zoophytes, shells, crustacea, fish, and reptiles. Its climate was obviously tropical, and its forms of life were allied to those which now occur only within a limited space from the equator. These forms are distinct not only from such as exist at the present day, but even from those which are discovered in the deposits which succeed. In many instances, the genus, in all, the species became extinct with this system, and it affords a striking illustration of creative power and wisdom, that of the myriads of types of organic existence which abounded in the waters of this peculiar ocean, not one survived in the seas which succeeded it.*

EXERCISES

ON THE CHALK FORMATION.

1. Describe the geographical distribution of the chalk deposits in this country.
2. Name the authors and collections.
3. Mention their occurrence in other countries.
4. State the distinctive features of this formation.
5. Mention the separate divisions of these strata in

* See Appendix C.

this country, and the mineral character, distinguishing features, and general characteristics of each.

6. State the opinions heretofore entertained of the origin of chalk and flint.

7. Explain those of later observers.

8. Describe the physical geography of the formation, and point out the area of the denudation of the chalk.

9. Mention the arrangement of the fossil fish by Professor Agassiz.

10. Name any remarkable fossil objects discovered in this formation.

11. Relate the discovery of the mososaurus.

12. State any facts of general and instructive interest connected with the history of these deposits.

13. Finally, convert the statements of the foregoing chapter into questions, and give answers on the most important points of its history.

CHAPTER XIII.

THE WEALDEN FORMATION.

WEALDEN FORMATION OF ENGLISH; FORMATION VELDIENNE OF FRENCH AUTHORS.

MUSEUMS: THE MANTELLIAN COLLECTION, NOW IN THE BRITISH MUSEUM; THOSE OF MR. HOLMES, OF HORSHAM, OF MR. BOWERBANK, MR. SAULL, AND SOME PRIVATE CABINETS IN SUSSEX.

AUTHORS: MANTELL, FITTON, MURCHISON, MARTIN.

CHARACTERISTICS: ITS UNIQUE CHARACTER AS THE ONLY FLUVIATILE SECONDARY FORMATION, ITS FOSSIL REMAINS BEING ALSO FLUVIATILE AND TERRESTRIAL; THE SPOILS OF THE RIVER AND THE LAND, NOT OF THE SEA.

There is one feature, as stated above, which will serve not only to identify this formation, but to invest it with new and peculiar interest. It is a fresh-water deposit, the only one of that character, with the exception, it may be said, of the coal, which exists in the vast range of the secondary rocks, the rest being all marine, the beds of ancient seas, as this is the deposit of a river; and affording, with the coal, almost the only testimony we possess of the ancient land. Its organic remains are, of course, of like fluviatile nature, resulting from the sediment of some enormous body of fresh-water, and consisting of plants, shells, and fish, and above all, of reptiles of enormous size.

Its Character discovered by Dr. Mantell.—We are only repeating a remark which has frequently

suggested itself in the course of these pages, that geology is a study far too extensive to be pursued in its whole extent by any single mind; and that the most eminent and successful cultivators of the science, while they have directed their observations to its general objects, have confined their peculiar attention to some single and fertile field. Thus, while a Lyell has most assiduously and successfully studied the tertiary deposits both of this country and the continent of Europe; while a Buckland has investigated the oolite, and discovered the megalosaurus; and a Murchison has explored the various formations extending from the heart of Wales to that of England, and from the county of Radnor to that of Gloucester, Dr. Mantell has the honour of having determined the true character of those singular deposits of which we are about to treat. And as in describing the preceding formation, we mentioned his labours as those of a most zealous and successful inquirer, we have now to narrate such additions to our stock of knowledge, as must entitle their author to rank in the highest order of original discoverers.

Former erroneous opinion of these Deposits.— The strata which we are describing are situated between the North and the South Downs, forming the district denominated the weald, from the German *wald*, a wood, the whole tract having at a former period been occupied by extensive forests. From lying between the two ranges of chalk-hills just mentioned, the locality was, some few years since, regarded as appertaining to that group, and being chiefly composed of clays, sands, and sandstones, was believed to belong to the green-sand, the lowest member of the chalk-formation; and according to this supposition its fossil remains should have been

of the same marine character as those of the other beds of the system. Dr. Mantell, however, was struck, at a very early period of his researches, by observing that the fossils which he collected from these deposits were none of them marine, but wholly of fluviatile character. Instead of the sea-weeds, sponges, corals, shells, and the other exuviæ of the ocean which he discovered in the chalk, he found only vegetable remains, leaves, branches, and stems of plants, with bones of reptiles, and fresh-water shells; in short the spoils, not of the sea, but of the river and the land. They all wore marks of long continued drift and transport, the stems were deprived of their branches, the branches denuded of their twigs and leaves, while the animal remains bore similar proofs of maceration and destruction, arising from the action of a river or a stream. Pursuing these inquiries with characteristic ardour and perseverance, Dr. Mantell was at length enabled not only to determine the true character of these strata, and to establish the fact, that instead of being of marine, they were of fluviatile origin; the deposits not of the ocean which deposited the chalk, but of some enormous river, some Ganges or Mississippi of the ancient earth; but from the evidence of drift and transport to which we have alluded above, he arrived at the conclusion that this peculiar district formed the delta of the ancient stream, the very point at which it poured its mighty waters into the sea.

This estuary nature of the wealden formation is universally acknowledged and received, the only statement at all differing from the character assigned to it by Dr. Mantell having been expressed by Professor Phillips, who has suggested that its deposits were possibly formed by several small streams, rather than by a single and

extensive river. But with all deference due to the opinion of so accomplished and so accurate an observer, the author of these pages would submit that the colossal forms of animal life discovered in these strata obviously bespeak an area of corresponding magnitude and extent. No petty stream, it may be assumed, could have furnished provision and abode for the large fish of these waters, the *lepidotus*, still less for the enormous *iguanodon*, and the possibly still more colossal *cetiosaur*.

Classification and Extent of the Wealden Deposits.—The beds of the entire group are usually separated into four divisions:—

1. The weald clay, a stiff blue clay, with beds of shelly limestone, called Sussex marble.
2. The Hastings beds, consisting of sands and sandstones, alternating with clays and limestones.
3. The Ashburnham beds, comprising clays, shales, and bluish grey limestones and sandstones.
4. The Purbeck beds, including clays, sandstones, and shelly limestones, called Purbeck marble. Limestones with layers of vegetable mould, and remains of trees in a vertical position; the fossil forest of Portland.

Geographical Distribution.—These deposits extend from Horsham to Hastings, where they terminate at the sea. They are, however, conceived to prevail beneath the British channel, since they re-appear in the valley of Braye, in the province of the Boulonnais, in France, thus occupying an area of 200 miles from west to east, and 220 from north-west to south-east, the total thickness being about 2,000 feet. Similar deposits occur in Scotland, and strata of like nature, resembling the weald-clay, and Hastings sand, have been discovered by M. Roemer, in Germany, where they occur near Helmsted, and extend westward from Hanover, by Minden to Iburg and Rheine, near Münster

in Westphalia, abounding in seams of coal of good quality, from one to three feet thick. Deposits of like character occur in the Isle of Bornholm, and with the progress of geological investigation, other instances of their occurrence will doubtless be traced, since the land which gave rise to the river of the weald was, unquestionably, drained by other rivers flowing in various directions.

THE ISLE OF PURBECK.—We will first advert to the outlying portions of this singular formation, as displayed in the Isle of Purbeck, the Isle of Portland, and the Isle of Wight, before we call attention to the weald itself. The isle, or peninsula of Purbeck, exhibits numerous instances of those dislocations of the strata which insular regions so constantly present. On the western side of the island in particular, the chalk is raised to a vertical position, and the wealden beds beneath are clearly displayed. The limestone which underlies the chalk is well known under the denomination of Purbeck marble. It is composed of small freshwater shells intermixed with the minute shelly coverings of a species of *cypris*. (See page 477.) This limestone was so extensively employed during the middle ages for the embellishment of ecclesiastical edifices, that there is scarcely a cathedral or church of importance in which the Purbeck marble is not used for the purpose of decoration.

ISLE OF PORTLAND.—But a neighbouring island affords similar phenomena still more interesting and instructive. The Island, as it is called, of Portland, is a bold promontory off Weymouth, sloping gradually towards the land: it is about four miles and a half in length, and two in breadth, and is united to the mainland by what is called the Chesil beach, a deposit

of pebbly shingle, the name of which is evidently derived from the German *kiesel*, a pebble.

The base of the island consists of Kimmeridge clay, and the oolite limestone, which supplies the celebrated Portland stone for building, on which is placed a mass of bituminous earth called the dirt-bed, which is an ancient vegetable soil, containing numerous fossil trunks of trees, standing erect at a height of from one to three feet, with the summits jagged as if they had been broken off by a hurricane.

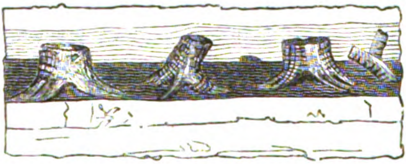


FIG. 225.

They are placed at the same distance from each other, as trees usually occupy in a forest, and have their very roots attached, showing that they now occupy the same spot on which they once lived and flourished.

The same bed of earth contains many remains of plants allied to the recent *cycas* and *zamia*, the former of which is figured below. From their rounded shape they are called birds' nests, by the workmen.

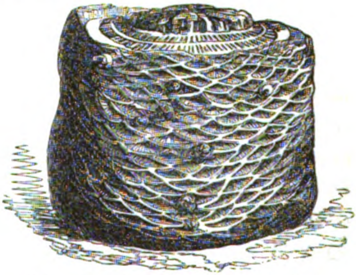


FIG. 226.—Mantellia nidiformis. Br.

They are termed *cycadeoidea*, by Dr. Buckland, but are styled *Mantellia*, by M. Adolphe Brongniart. The dirt-bed is also traced on the main-land, being seen in the same relative position in the cliffs of Lulworth Cove, on the adjacent coast of Dorsetshire, where, however, the strata having been inclined to an angle of 45 degrees, the dirt-bed, with its fossil trees, is inclined with them, presenting the most convincing evidence of the disturbance of strata, since it is obvious that the trees must have grown erect and subsequently have been inclined with the bed in which they grew.

It has recently been ascertained that the forest of the dirt-bed was not the earliest vegetation of this locality. Two beds of carbonaceous clay have been discovered beneath it, one of which contains *cycadeoidea* in an erect position, from which fact, in conjunction with the rest, the following changes are conceived to have occurred in this remarkable and highly instructive district.

1. The existence of the sea which deposited the oolite.

2. Land which supported the vegetable soil with *cycadeoidea.*

3. A lake or estuary in which freshwater strata were deposited.

4. A second prevalence of dry land, on which flourished *cycadeoidea*, and a forest of dicotyledonous trees.

5. A second submergence under fresh water, during which the wealden strata were gradually formed.

6. A prevalence of the waters of the ocean during the period of the chalk formation.

And yet the multifarious changes of this remarkable region appear to have taken place in so gradual, so

gentle a manner, that not only have the fossil trees retained their position, but even a bed of loosely-coherent earth has not been swept away amid the revolutions of which this singular locality has been the scene!

WEALDEN STRATA OF THE ISLE OF WIGHT.—The wealden beds are extensively developed at the back of the island, and constitute the foundation-deposits of its southern part, occurring at Sandown Bay, Brooke, and Mottestone. Portions of trees and vegetable remains are frequently washed out of the cliffs, and bones from the wealden strata, which here form the bed of the British Channel, are cast on this and the adjacent shores of the mainland.

ORGANIC REMAINS OF THE WEALD.—The fossil relics of this formation consist of vegetables, freshwater shells, and shelly limestones; with remains of birds, fishes, turtles, pterodactyles, or winged reptiles, and reptiles of colossal size. The shells are almost exclusively of freshwater origin, consisting of the genera *cyclas*, *unio*, and *paludina*, with some occasional admixture of marine and estuary species. The reptile remains have been almost wholly discovered and determined by the inquiries of Dr. Mantell, and are chiefly referable to the genera *iguanodon*, *hylosaurus*, *plesiosaurus*, *megalosaurus*, *cetiosaurus*, &c. The plants are entirely of monocotyledonous order, none of dicotyledonous structure having been discovered in these deposits. They consist chiefly of such as are allied to the fern, palm, yucca, dracæna-draco, or dragon's blood plant, and other vegetable productions of the torrid zone, among which are examples of *sphenopteris*, *clathraria*, *lonchopteris*, &c. &c. The first two are depicted on the next page.

FIG. 227.—Sphenopteris Mantellii.

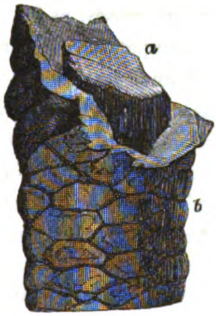


FIG. 228.—Clathraria Lyellii. A plant allied to the palm; *a*, the axis; *b*, the false bark with markings of the attachment of the leaflets.

The shells are of freshwater species, chiefly of the genera, *cyclas, unio*, and *paludina*.

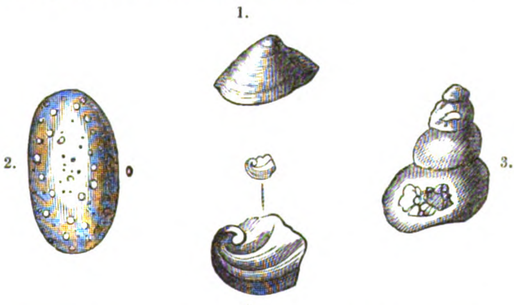


FIG 229.—1. Cyclas. 2. Cypris granulosa. 3. Paludina vivipara. 4. Neritina, natural size and magnified.

Sussex Marble.—The weald clays contain beds of limestone made up of a few species of the univalve above-mentioned, called *paludina*, a freshwater snail, common in rivers and lakes. This substance, which when polished is called Sussex marble, was used for orna-

mental purposes, as far back as by the Romans, during their occupation of our island, and possibly by our British ancestors before them. During the middle ages it was employed for the decoration of cathedrals and churches, and is still extant in many of our ecclesiastical edifices. It forms a row of columns in Chichester cathedral; and in that of Canterbury, the throne of the Archbishop is formed of the same material. How instructive is the fact, that the mere slime and mud of this river of the past, together with the snail-shells which they contained, have been elaborated by the chemistry of nature into a substance, which, during two thousand years, has ministered to the wants, furnished the luxuries, and served for the most hallowed uses of man; supplying the materials from which he has alike adorned his dwellings, constructed the tombs of the departed, and embellished the temples of his God! A highly interesting proof of its employment by the Romans was afforded by the circumstance, that while digging the foundation of the present Council-house, at Chichester, in 1723, the workmen discovered a slab of grey Sussex marble, which they ignorantly fractured, but which being collected, bore an inscription of which the following is a translation, and which records the dedication of a temple, as follows:—

"The college, or company of artificers, and they who preside over sacred rites, or hold offices there, by the authority of King Cogidubnus, the legate of Tiberius Claudius Augustus, in Britain, dedicated this temple to Neptune and Minerva, for the welfare of the imperial family; Pudens, the son of Pudentinus, having given the site."

The stone was of grey Sussex marble, was six Roman feet long, and two broad, and the letters, which are carved with singular correctness are, in the first two

lines, three inches, and in the others, two and three fourths in length. It was presented, soon after its discovery, to the Duke of Richmond, and is still preserved at Goodwood, affixed to the wall of a temple erected in the gardens. The learned antiquaries of that day, particularly Roger Gale, who has printed a long memoir respecting this inscribed stone, in the Philosophical Transactions, vol. xxxii. No. 379, have decided from internal evidence, that it is the earliest memorial of the Romans hitherto discovered in any part of Great Britain.

FIG. 230.—Sussex marble.

FOSSIL FISH.—The strata of the weald have also yielded the scales, rays, teeth, and bones of fish, chiefly

of species allied to the *lepidotus*, or bony pike; a fish which now inhabits the vast lakes of the North American continent. These remains usually occur in a fragmentary condition, occasioned by the transporting action to which they have been exposed. Other species are also discovered, allied to the shark, and ascribed to the genera *pycnodus*, and *hybodus*, the whole of the fishes discovered in the weald being essentially distinct from those of the chalk.

Turtles.—The bones and other remains of turtles referable to one marine, and two freshwater species, the *emys* and *trionyx*, have also been exhumed from these deposits. The teeth and bones of crocodiles of two species, the one allied to the gavial, or the variety with long slender beaks and muzzles, the other more nearly resembling the common crocodile, have also been discovered; and at Swanage, in Dorsetshire, a highly interesting specimen of a crododile, termed by Professor Owen *goniopholis*, from the angular nature of its scutes, was some time since brought to light, which comprised a considerable portion of the osteology, including the two jaws, the lower containing two teeth *in situ*, with several other scattered teeth, portions of the pelvis, the ribs, the dermal plates, &c. The specimen passed, with the rest of Dr. Mantell's collection, to the British Museum, where it is now publicly exhibited.

Colossal Reptiles, the Iguanodon.—But the most important discoveries effected by Dr. Mantell, in a region which he has raised to geological celebrity and interest, consist of those enormous reptiles which he has exhumed from this locality. For a complete and highly interesting account of these researches, the reader is referred to Dr. Mantell's own writings, par-

ticularly his Fossils of Tilgate Forest, and his Geology of the South-east of England. The following sketch will afford some idea of his arduous and persevering labours, and their highly important and successful results. He had long been in the habit of discovering bones which he was unable to refer to any known forms of existence, recent or extinct. Their characters were such as referred them to a reptilian type, yet their enormous size seemed to preclude such a supposition, for a reptile larger than an elephant seemed too monstrous for belief. At length, the discovery of the mere mutilated fragment of a single tooth induced so acute an observer to conceive the existence of a gigantic herbivorous creature, holding the same rank among reptiles which was occupied by the elephant and mastodon among the mammalia. The following illustration, supplied from the work of Dr. Mantell, will serve to convey an idea of the teeth.

FIG. 231.—Tooth of Iguanodon.

They are of prismatic form, with prominent ridges in front, and notched or serrated edges; the enamel is thick before and thin behind, so as constantly to maintain a sharp and cutting edge. The structure of the

teeth, and the wearing away of the surface, prove that they are referable to a species that fed on vegetables; the absence of a fang, and the appearance of the base, which is not broken off, but indented, show that the fang has been absorbed by the pressure of a new tooth, which has grown up and supplanted the old one. Dr. Mantell having recognised in the above the characters of the reptilian type of existence, examined the various dental structures of this peculiar race of animals, till in the teeth and jaws of the *iguana* he recognised the miniature resemblance of its colossal prototype.

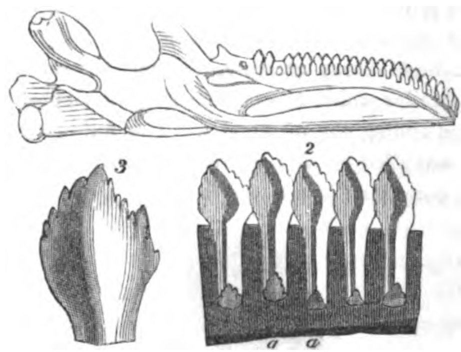


FIG. 232.—Jaw and teeth of Iguana.

In the above figure, No. 1, is the inner surface of the right side of the upper jaw; No. 2, a portion magnified four diameters; No. 3, a single tooth, largely magnified. At *a*, *a*, the intrusion of the new tooth into the base of the old is beautifully shown. The jaw forms a parapet on the outside of the teeth, but they have no protection inside, except the gum. The prismatic form of the teeth, the notched and serrated edge, the re-

placement of the old tooth by the new, the absorption of the fang, the mode of insertion in the jaw, the singularly minute size of the teeth, contrasted with that of the creature to which they belong: these, with other characters, amply sufficed to ally the recent with the fossil species, and induced its discoverer to name the new-found creature the *iguanodon*, a term signifying that the animal had teeth resembling those of the *iguana*. It may be added that the *iguana* is a land-lizard, a native of many parts of America and the West Indies. They are from three to five feet in length, feeding chiefly on insects, and the tender shoots of vegetables and plants.

Horn of the Iguanodon.—Many species of the *iguana* have large serrated processes along the back, while some have warts or horny protuberances on the head. The *iguana cornuta*, in particular, which is a native of St. Domingo, has a small conical horn or process;

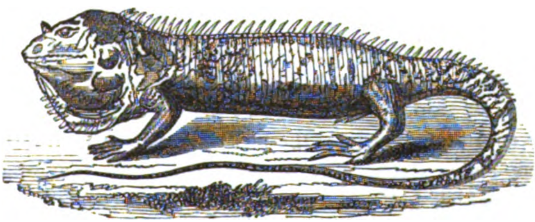


FIG. 233.—Iguana cornuta.

the fossil relic depicted on the next page has, therefore, been referred by Dr. Mantell, with the sanction of Cuvier, to its extinct prototype, and is conceived to be the horn of the iguanodon.

FIG. 234.—Horn of the Iguanodon.*

SIZE OF THE IGUANODON.—From a careful comparison of some of the fossil bones with those of the existing iguana, Dr. Mantell arrived at the following approximation to the dimensions of this gigantic saurian. Extreme length, 70 feet; circumference of the body, 14½ feet; length of the tail 52½ feet; and of the hind foot, 6½ feet. Indeed the most casual observer who may visit the British Museum has only to clothe, in idea, the colossal bones there exhibited, (one thigh-bone being three feet in length and eight inches in diameter), with their appropriate investiture of flesh, scales, or skin, to recognise the gigantic dimensions of this enormous reptile of the past. Vast as the proportions above stated may appear, there are individual bones which indicate a much larger size, while specimens are frequently acquired by other collectors, which alike bespeak the still more gigantic dimensions of the creatures of whom they formed a part. The cabinet of Mr. Saull contains specimens of enormous size, among

* The above specimen, which is placed with the rest of Dr. Mantell's collection in the British Museum, was considered unique, till Mr. Bass, jun., of Brighton, a short time since, possessed himself of another.

which an enormous claw-bone is particularly to be mentioned; while Mr. Holmes, of Horsham, has some chevron-bones, those attached to the caudal vertebræ, or joints of the tail, which must have belonged to an individual far surpassing even the colossal proportions cited above.

The Maidstone Iguanodon.—The discovery of the Maidstone iguanodon, so called from its having been discovered near Maidstone, which comprises a larger portion of the entire skeleton than had previously been found in a connected form, has served to confirm, in several important particulars, the assumptions which Dr. Mantell had been induced to form, relative to its general structure. This specimen was discovered in the green-sand formation, a circumstance which serves to prove that the existence of the genus was protracted till an early period of the chalk formation; and it is conceived that, as the remains of the crocodiles and alligators are now borne by tropical rivers to the ocean, into which they discharge themselves, so these remains have, in like manner, been floated from the then existing river to the sea into which it flowed.

The Hylosaurus.—A reptile of another genus, but of the same class, was also brought to light by the same eminent discoverer from the strata of this singular region. The peculiarity of this creature consists in the large angular spinous bones which lie embedded with the skeleton, and which are thus explained. Many existing iguanas, as previously mentioned, (see *iguana cornuta*, p. 483.) have a fringe of cartilaginous spines, extending from the neck to the tail. In the extinct reptile this appendage is conceived to have been of bone, and to have in like manner been inserted along the back of the

animal. The creature is named *hylosaurus*, a term intended to signify that it is the lizard of the weald, or the wood, from being found in that peculiar district, and the chief portions of its osteology, discovered by Dr. Mantell, are now displayed in the British Museum.

PTERODACTYLES.—Single bones, which are long and slender, and adapted for an animal capable of flight, have been found in the same formation, and have been referred to those singular creatures, whose osteology, as discovered by Cuvier, in formations of still earlier date, is depicted below. The name literally indicates that they were wing-toed animals, analogous to the bats of the present day, and uniting the characters of the bird and the reptile.

FIG. 235.—Pterodactylus crassirostris. Goldfuss.

The enumeration of Dr. Mantell's discoveries in this peculiar district may be closed, by mentioning the occurrence of the bones of birds, supposed to be allied to the heron, which have been found in the same deposits, constituting the earliest evidence of the existence of the feathered tribes in the history of the ancient earth.

The collection formed by this distinguished discoverer from these strata has been removed, as before mentioned, to the British Museum. It comprises a vast assemblage of teeth and bones, chiefly referable to those reptile forms of life which we have already described, as well as of others which have not hitherto been identified with any known species, together with similar remains of the plesiosaurus and megalosaurus, which also occur in the underlying deposits of the oolite and lias. Professor Owen has directed his peculiar attention to these highly interesting remains, and among the most recent additions to our previous stores of knowledge in this department, we would mention the following circumstance. Among other objects heretofore unappropriated to any definite species, are a suite of four enormous vertebræ, which Dr. Mantell had provisionally assigned to the *iguanodon*, though he had repeatedly expressed to the writer of these pages his conviction that they belonged, in all probability, to some other and still more gigantic reptile. Professor Owen, on a careful inspection, has referred them to *cetiosaurus*, a new and colossal genus of saurians, discovered by himself in the oolite formation.

Denudation of the Strata of the Weald.—In conclusion, we would advert to the evidences of denudation before alluded to, as so extensively presented throughout this and the superincumbent formation. The

removal of the chalk, and probably of the overlying tertiary deposits; the evident abrasion of the wealden beds themselves; the proofs of displacement and fracture which they present; the anticlinal axis exhibited throughout a considerable part of their range; the fissures which, extending at right angles to the anticlinal line, form the present drainage of the district, and constitute the beds of the rivers Arun, Adur, Ouse, and Cuckmere; these, with other facts of like import, obviously prove that these strata have undergone upheaval and disturbance, and consequent fracture and dislocation, on the most extensive scale, at a comparatively recent period, probably during the tertiary epoch, and subsequent to the deposition of the chalk.

EXERCISES

ON THE WEALDEN FORMATION.

1. Explain the derivation of the term weald.
2. Name the authors and collections of fossils.
3. Mention its most important characteristics.
4. Describe the geographical distribution of its deposits.
5. Point out the instances of their occurrence in foreign countries.
6. Name their discoverer.
7. Describe the general classification of its strata.
8. Mention the most important localities of its occurrence.

9. Describe its chief organic remains, and the inferences deducible from their occurrence.

10. Point out the chief physical features of these strata and their evidence of disturbance.

11. Name any peculiar phenomena which are observable in deposits of this nature.

12. State any particulars of general or local interest connected with the history of this formation, and pursue the method of question and answer suggested in the previous chapter.

CHAPTER XIV.

OOLITE FORMATION.

OOLITIC FORMATION OF ENGLISH; CALCAIRE JURASSIQUE OF FRENCH; JURAKALK, AND ROGENSTEIN OF GERMAN AUTHORS.

MUSEUMS:—GEOLOGICAL SOCIETY; BRITISH MUSEUM; THAT OF DR. BUCKLAND; THE BATH, BRISTOL, YORK, SCARBOROUGH, HULL, WHITBY, AND GRANTHAM MUSEUMS; WITH NUMEROUS PRIVATE COLLECTIONS.

AUTHORS:—BUCKLAND, LONSDALE, SMITH, PHILLIPS, DE LA BECHE, MURCHISON, BOBLAYE, DE CAUMONT, DESNOYERS, GOLDFUSS, &c.

CHARACTERISTICS:—MARINE, CONTAINING THE USUAL MARINE EXUVIÆ, WITH OBJECTS DRIFTED FROM THE LAND, AMONG WHICH ARE REMAINS OF TWO SPECIES OF MAMMALIA, OF THE MARSUPIAL ORDER; ITS ECONOMICAL VALUE, AS FURNISHING THE GREAT SUPPLY OF BUILDING-STONE.

DESCENDING a step in the scale of deposits, we reach the oolite system, which underlies the wealden, or, where this is wanting, the chalk formation. Its name is derived from the Greek words, *ωον*, an egg, and *λιθος*, a stone, because it is formed of small egg-like grains, like those composing the roe of a fish, the nucleus of which, on microscopic investigation, is found to be some minute organic substance, usually a fragment of a coral, or a shell. The Germans, in their rich and significant language, term it *Rogenstein*, or roe-stone.

GEOGRAPHICAL DISTRIBUTION OF THE OOLITE.—The series of these deposits commences at the Isle of Portland, and the adjacent coasts of Dorset; and follows a winding course through the counties of Dorsetshire, Somersetshire, Gloucestershire, Oxfordshire, Northampton-

shire, Lincolnshire, and Yorkshire, where it terminates at the sea, near Scarborough.

On the continent, the formation occurs in Normandy, and diverging into various branches of hills, traverses France, forms the mass of the Jura mountains, (whence it is frequently called the Jura limestone,) and part of the Alps, and is farther developed in Germany and Poland, as well as in Portugal and Spain.

The three formations of the oolite and lias, and new red sandstone, are frequently called the medial secondary formations. The oolite group is highly valuable in an economical point of view, from its consisting, in a considerable degree, of limestones adapted for architectural purposes.

The following are the principal subdivisions of the oolite.

Upper.	Portland stone. Kimmeridge clay.
Middle.	Coral rag. Oxford clay.
Lower.	Cornbrash and forest marble. Great oolite and Stonesfield slate. Fuller's earth. Inferior oolite.

The Portland stone we have already, in some measure, described as a limestone, abounding in ammonites, trigoniæ, &c. &c.

The Kimmeridge clay is a blue stiff clay, with septaria, and bands of sandy concretions.

The coral rag, a limestone, composed of corals, with echini and shells.

The Oxford clay, a dark tenacious clay, with septaria, and numerous fossils.

The corn-brash, a coarse shelly limestone.

The forest-marble, sand, with concretions of arenaceous limestone.

The great oolite, calcareous limestone and freestone, containing corals, shells, and reptiles, while the Stonesfield slate comprises land-plants, insects, reptiles, and two species of mammalia.

The fullers'-earth beds, sands and marls, with fullers'-earth.

The inferior oolite, a coarse, shelly limestone, with ferruginous sand, and sandy limestone, with shells.

The upper deposits usually repose on Kimmeridge clay, the middle on Oxford clay, and the lower on the lias.

The following are some of the most usual shells of the oolite:—

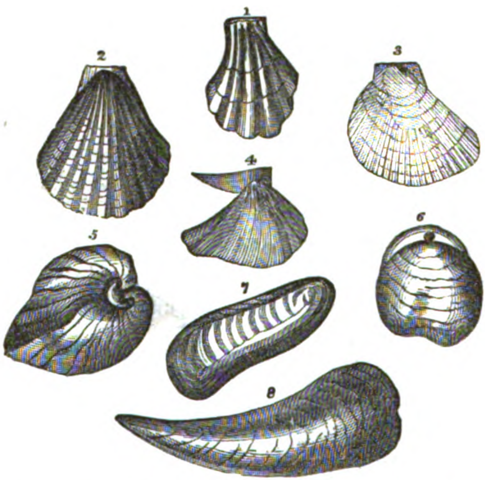


FIG. 236.—1. Lima rudis. 2. Pecten vagans. 3. Plagiostoma rigidum. 4. Avicula inequivalvis. 5. Trigonia costata. 6. Terebratula globosa. 7. Modiola plicata. 8. Pinna lanceolata.

We have already mentioned the circumstance of some new forms of ammonites having recently been discovered, chiefly in the Oxford clay of this formation, which are remarkable for presenting a long, narrow, spatulate projection extending from the mouth, which however is not considered as having contributed to any actual function of the animal inhabitant, but to present merely a specific distinction, resembling an analogous structure in certain species of *sepia*, or cuttle fish. The accompanying woodcut depicts one of these forms.

FIG. 237.—Ammonites Elizabethæ.

One of the limestones of the middle oolite has been named the "coral rag," because it consists of continuous beds of petrified corals, retaining in many cases

the position they occupied when growing in the sea, and consisting chiefly of the genera *caryophillia* and *astræa*.

CRINOIDEA.—The lily-encrinites, or stone-lilies, as they are sometimes called, occur in the oolite, and at Bradford, in Wiltshire, in a clay appertaining to the forest marble, the species termed the pear-encrinite are extremely abundant.

FIG. 238.—Apiocrinites rotundus.

ORGANIC REMAINS OF THE STONESFIELD SLATE.—The village of Stonesfield, in which it occurs, is situated in a valley which has been deeply excavated by means of shafts and galleries, for the purpose of procuring the

slate which is used for economical purposes. The organic remains here discovered are numerous and important, the vegetables consisting of marine plants, referable to fuci, palms, tree-ferns, and others allied to the *zamia* and *cycas*, together with a genus of *liliaceæ*, seed-vessels, leaves, and stems of *coniferæ*, &c., &c. The animal exuviæ consist of the teeth and bones of crocodiles, bones and plates of turtles, bones of pterodactyles, or winged reptiles, with osseous fragments, apparently those of saurians, and the teeth, scales, fin-bones, and rays of fishes, with many of the usual fossils of the other oolitic strata. Its geological position has been ascertained by W. Lonsdale, Esq., the late curator of the Geological Society, who has investigated the whole of this formation, with his accustomed industry and success, to be the base of the great oolite.

The Megalosaurus.—It was in this deposit that Dr. Buckland discovered the bones and teeth of a colossal reptile, which he has thus named. It appears to have been a gigantic carnivorous animal, allied both to the crocodile and monitor, and from the dimensions of the separate bones hitherto found, for the entire skeleton has never yet been discovered, is presumed to have been forty or fifty feet in length. The bones of the thigh and leg are not solid in the centre, as in the *amphibia*, but hollow for the reception of medullary substance, as is the case with terrestrial animals. The shape of the head indicates it to have terminated with a long and narrow snout. The teeth prove it to have been carnivorous, exhibiting peculiarities of structure which combine the powers of the knife, the sabre, and the saw.

FIG. 239.—Tooth of Megalosaurus.

Its remains, like those of the *cetiosaurus*, another colossal saurian of the oolite, have also been discovered, as we have previously mentioned, in the wealden strata, by Dr. Mantell.

THE DIDELPHYS, OR MARSUPIAL ANIMAL OF STONESFIELD.—This remarkable locality has yielded several highly valuable memorials of the past, one of which is figured below.

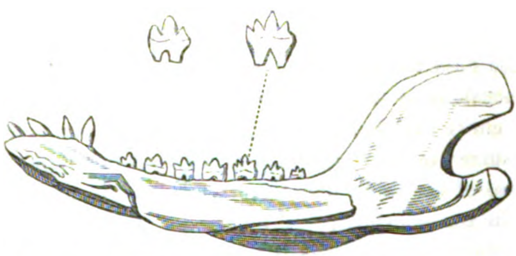


FIG. 240.—Jaw of the Didelphys or Thylacotherium of Stonesfield.

This jaw, on its first discovery, was submitted to the inspection of Cuvier, who pronounced it to be that of a marsupial animal, allied to the *didelphys*, or opossum.

This decision was received as one of great interest and importance, since it affords proof of the only instance of a creature of the class mammalia, which has been discovered in the secondary deposits, the chief inhabitants of which were the enormous, oviparous quadrupeds, freshwater, and marine—the colossal reptiles, in short, of the land and sea, which we are now in course of describing. A short time since, the decision of Cuvier was called in question, by M. de Blainville, who, from an examination of the cast of the original jaw, declared his opinion that it was that of a reptile. A long and animated discussion ensued, in which Professor Owen vindicated the decision of Cuvier, and after a lengthened controversy it was decided from the chair of the Geological Society, by Professor Whewell, the President, that the weight of evidence was in favour of the mammalian character of the relic. The objections of such an authority as M. de Blainville have, however, thrown a doubt upon the subject, which renders it extremely desirable that a microscopic examination of a tooth should, if practicable, be undertaken; a mode of inspection which, in such hands as those of Professor Owen, could not fail to decide the question beyond the possibility of dispute.

Coal-money.—An object of some interest to antiquaries may be mentioned with reference to this formation. In the barrows and burying-places of our British ancestors, objects have been found which are known to collectors by the above name of coal-money. They are composed of the Kimmeridge clay of this formation, which is so strongly impregnated with bitumen that it will burn in an imperfect manner, somewhat like coal. They are of circular forms, varying in size from one inch

to about three inches in diameter, and from one-eighth to half an inch in thickness; they appear to have been turned in a lathe, and some have been found bearing circles and angles, traced with considerable exactness. Some collectors are of opinion that they were not intended for money, but were merely part of the machinery of a turning-lathe. This supposition, however, is difficult to reconcile with the markings just mentioned, as well as with their being constantly found in tumuli, and places of interment, associated with urns, pottery, ornaments, and arms; in short, in situations, and under circumstances in which coins are generally discovered. These facts tend strongly to confirm the opinion expressed by Sir Richard Colt Hoare, and other antiquaries, that they were employed as the representatives of money, that is, not as as a medium of circulation, but as symbols of value, and were introduced into this country by the Carthaginians, or Phœnicians, who traded with our British ancestors for tin, copper, and other metallic productions.

Specimens are by no means uncommon in the cabinets of antiquaries; there are several examples in the collections of the Geological Society, and the writer has met with others in the store-cases of the British Museum.

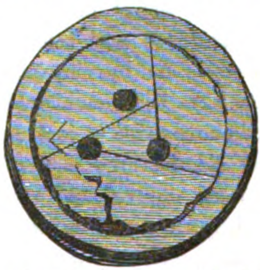


FIG. 241.—A specimen inscribed in the style above-mentioned.

Coal of the Oolite.—In the district north of the Humber, the lower beds of this formation assume a new character, and the forest marble and great oolite are replaced by beds of sandstone, shale, and carbonaceous matter. The coal, though inferior both in quality and extent to that of the true carboniferous period, never exceeding sixteen inches in thickness, is of considerable local value. Fossil plants are found in the sandstones which accompany the coal; and in Gristhorp Bay a seam of shale is traceable for a considerable distance containing leaves of ferns, *equiseta*, *cycadeæ*, &c., many specimens of which are placed in the British Museum. A similar deposit of coal was discovered at Brora, in Scotland, and was worked from patriotic motives, by the late Duke of Sutherland, but, from the great loss incurred, the works are now given up.

EXERCISES

ON THE OOLITE FORMATION.

1. State the derivation of the term oolite.
2. Describe the general geographical distribution of these beds.
3. Name their localities in other countries.
4. Mention the chief authors and collections.
5. Describe the principal characteristics of the system.
6. Point out the sub-divisions of the beds.
7. Mention their respective mineral characters.
8. State their principal fossil remains.
9. Describe any fossil objects of extraordinary nature

and interest which have been discovered in this formation.

10. Trace on the map and commit to memory the general direction of the strata, and name the counties in which they occur.

11. Mention their economical and commercial relations.

12. State any facts of a generally interesting and instructive nature connected with these deposits, and consult the foregoing epitome for questions and answers on the principal features of their history.

CHAPTER XV.

THE LIAS FORMATION.

LIAS OF ENGLISH; CALCAIRE A GRYPHITES OF FRENCH; AND GRYPHITENKALK AND JURA-KALK OF GERMAN AUTHORS.

MUSEUMS:—BRITISH MUSEUM, THOSE OF SCARBOROUGH, WHITBY, OF VISCOUNT ENNISKILLEN, SIR P. EGERTON, PROFESSOR SEDGWICK, AND GENERALLY THOSE OF DORSETSHIRE, YORKSHIRE, AND THE MIDLAND COUNTIES.

AUTHORS:—BUCKLAND, CONYBEARE.

CHARACTERISTICS:—A MARINE DEPOSIT CHIEFLY REMARKABLE FOR ITS REMAINS OF ENORMOUS REPTILES, PRINCIPALLY OF THE GENERA ICHTHYOSAURUS AND PLESIOSAURUS.

THE lias is conceived to owe its name to a provincial corruption of the word layers, used by the workmen to denote those laminations or partings, into which many of its shales are liable to divide.

GEOGRAPHICAL DISTRIBUTION.—The lias, like the oolite, forms a belt which extends across our island, from its south-western to its north-eastern shores, from Lyme-Regis, in Dorsetshire, to the north of Whitby, where it is lost beneath the moorlands of the Yorkshire coast. It accompanies the oolite with considerable regularity, from Lyme-Regis through Dorsetshire and Somersetshire to Gloucestershire, in which county, about six miles south of Gloucester, its western portion diverges still farther to the west, and pursues a tortuous and intricate course, among the counties of Somersetshire, Gloucestershire, Monmouthshire, and Glamor-

ganshire, attended with outlying portions and detached masses. Its eastern portion continues a regular track through parts of Gloucestershire, Worcestershire, Warwickshire, Leicestershire, Lincolnshire, and Nottinghamshire, into Yorkshire.

On the continent, this formation is largely developed, in the north and south-east of France, in Switzerland, and Germany.

In some countries, it is wanting over extensive areas; in the vast continent of America no strata of this nature have yet been discovered, nor has any part of the world yielded organic remains of a character or interest vying with those which have been brought to light in this country, an unrivalled collection of which constitutes the most important feature of the assemblage of organic remains, exhibited in the mineral-galleries of the British Museum.

The strata of the lias consist of

1. The upper lias shale; intercalated with the lowest beds of the oolite, and containing saurian remains, ammonites, belemnites, &c.
2. Lias marls; calcareous, sandy, and ferruginous.
3. Lower lias clay and shale; with intercalations of sands and septaria, abounding in shells.
4. Lias rock; a series of laminated limestones, with partings of clay.

Fossils of the Lias.—The vegetable remains of this system comprise several species of *cycadeoidea*, which have been discovered at Lyme-Regis, and of *coniferæ*, occurring at Whitby.

Fossil Shells.—The shells of this formation are numerous and interesting, the following plate represents some of the principal forms.

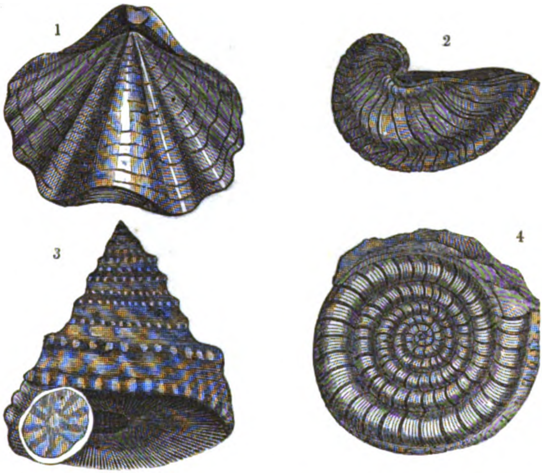


FIG. 242.—1. Spirifer Walcottii. 2. Gryphæa incurva. 3. Trochus Anglicus. 4. Ammonites Conybeari.

Fossil Fish.—These resemble, as to genera, those of the oolite, differing materially from those of the chalk.

Mr. Buckman, of Cheltenham, has investigated, with much ardour and success, the oolite and lias formations, as developed in the vicinity of that town, the results of which will shortly appear in the second edition of Mr. Murchison's Geology of Cheltenham, which has been confided to his care for publication. Meantime the writer is enabled, by the kindness of his friend, to state, that he has discovered several features of novelty and interest in the oolite, in particular the Stonesfield slate of the Cotswold hills, which was previously almost unknown. We have already named, that he has discovered several new forms of shells in the lias, among which are three new species of *arca*, to one of which the author of these

pages would beg to attach the name of its discoverer,

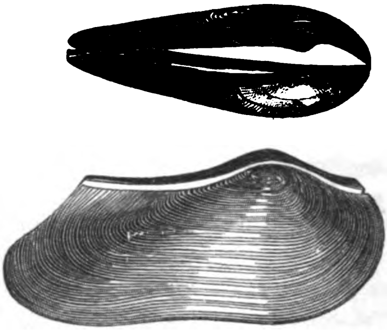


FIG. 243.—Arca Buckmanni.

The following are the specific distinctions of this shell, the genus never having been previously discovered in this formation.

Shell gibbose, transversely sulcated, (lines of growth,) and finely striated longitudinally, three times as wide as long, anterior end somewhat pointed towards the base, beaks remote, yellow lias of Cheltenham.

From a variety of forms of *spirifer*, which he has also discovered in this deposit, we would select a species termed by its discoverer,

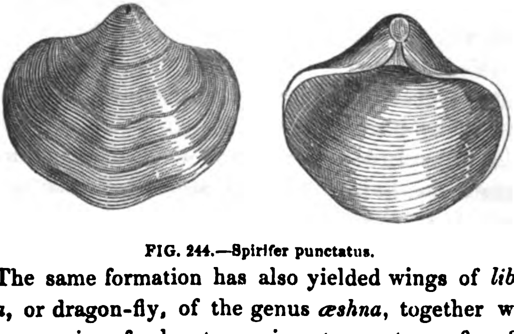


FIG. 244.—Spirifer punctatus.

The same formation has also yielded wings of *libellula*, or dragon-fly, of the genus *æshna*, together with other remains of coleopterous insects, crustacea, &c., &c.

Reptiles of the Lias.—But the most magnificent objects of the Creator's hand, which not this deposit alone, but it may be said, the universal formations of the earth can furnish for our study and admiration, are afforded by the colossal *enaliosaurians*, or marine reptiles, the *ichthyosauri* and *plesiosauri*, which have been exhumed from this deposit. The structure of these remarkable creatures is now so generally known, that it may be sufficient to repeat a few only of their leading characteristics.

The Ichthyosaurus, (from ιχθυς, fish, and σαυρα, a lizard.)—This name, which was bestowed by C. König, Esq., of the British Museum, is intended to describe an animal, the osteology of which, especially as regards the vertebræ, more nearly approaches the character of the fish than of the lizard. Like its congener, the *plesiosaurus*, it is remarkable for uniting such combinations of structure as are now distributed through various classes and orders of animals, but no longer exist in any one. Thus it possessed the snout of a porpoise, the teeth of a crocodile, the head of a lizard, the sternum or breastbone of the *ornithorhynchus*, the paddles of a whale, and the vertebræ of a true fish. Its general outline is considered to have most nearly resembled that of the modern porpoise or grampus. The teeth are sharp, conical, and striated, resembling those of a crocodile, but they are more numerous; they are also supplied by replacing teeth, in the same manner as in the crocodile. The eye was of enormous magnitude, far surpassing that of any living animal, and the sclerotic or outer coat is composed of thin, bony plates, arranged round the central opening which once contained the pupil, as is the case in some species of birds, especially the golden

eagle, an arrangement which gives an immense extent and power of vision. The sternum, or breast-bone, resembles in structure that of the *ornithorynchus*, and its construction in both creatures was obviously intended to bestow the power of descending or ascending in the water with great rapidity, in order to allow the opportunity of breathing. The paddles were four, the two fore-paddles being large, composed of about one hundred bones, while the hinder are smaller, consisting only of thirty or forty. The vertebræ are concave and hour-glass shaped, like those of the sharks and other fishes. Professor Owen has established ten distinct species of this genus.

THE PLESIOSAURUS, (from *πλεσιον*, akin to, and *σαυρα*, a lizard.)—This creature, as its name imports, was more nearly allied to the lizard than the fish, especially as regards the character of its vertebræ. Like the *ichthyosaurus*, it united in its structure the attributes of various and dissimilar classes and orders, combining the head of a lizard, the teeth of a crocodile, a neck of enormous length, resembling the body of a serpent, a back and tail having the proportions of an ordinary quadruped, the ribs of a chameleon, and the paddles of a whale. It is conceived to have so far differed in its habits from the *ichthyosaurus*, that while that creature sought rather the profound depths of the ocean, the *plesiosaurus* is considered to have swam upon or near the surface of shallow waters; arching back its long neck like the swan, and occasionally darting it down at the fish which floated within its reach. The number of species now established by Professor Owen amounts to twenty. The series exhibited at the British Museum consists of two separate collections purchased of Mr. Hawkins, and

comprising specimens of unequalled interest and value, together with similar objects received as presents or acquired by purchase.

THE PLESIOSAURUS RUGOSUS.—The collection has been recently increased by a valuable addition which was presented by one of the trustees, the nobleman who has honoured these pages by permitting them to be dedicated to the Duke of Rutland. The specimen was purchased by his Grace, and presented to the British Museum, where, under the assiduous care and superintendence of C. König, Esq., it was so skilfully relieved from the clay and stone by which it was obscured, and its osteological characters so clearly developed, that when Professor Owen inspected the specimen, he recognised it as confirming the reality of a new species, which he had been induced provisionally to establish, from the inspection of a few fragmentary vertebræ, which had come into his possession. These vertebræ presented certain rugose or wrinkled markings at their edges, from which appearance this distinguished savant concluded that this character pervaded the entire osteology, and hence he was induced to bestow on the species the name of *plesiosaurus rugosus*. On examining the specimen presented by His Grace, the Professor traced, throughout the entire skeleton, the prevalence of that rugose marking which he had assumed as characteristic of the whole structure, from the features of the vertebræ alone. The details of this discovery will be made public in a paper which he is preparing for the Geological Society; in the meantime the statement here submitted will convey a general idea of this interesting fact. The accompanying figure affords a faithful representation of the specimen itself.

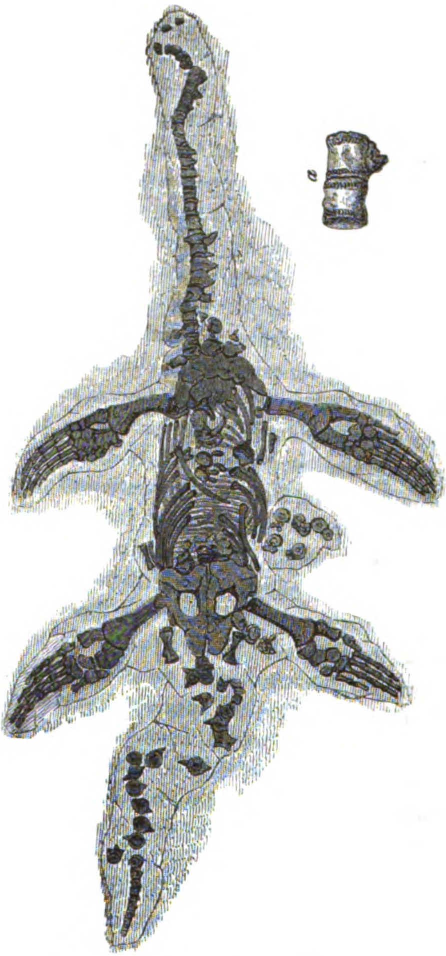


FIG. 244.—Plesiosaurus rugosus. Owen.

THE PLESIOSAURUS GRANDIPINNIS.—The most entire and perfect specimen of plesiosaurus yet brought to light is one recently discovered at Whitby, which has been purchased at the price of £230 for the Fitzwilliam Museum, at Cambridge, though it certainly were to be wished, that so admirable an example of this singular class of creatures had been obtained by the trustees of the British Museum, and added to the national collection, where it would, of course, have been far more accessible to the general public than in the local depository, however distinguished, in which it is now placed. The following is a figure of the object, which has been established, by Professor Owen, as a distinct species, from the large size of its paddles, and hence termed by him *p. grandipinnis*. The total number of species determined by the professor is twenty.

From the state of perfection in which this and other specimens have been discovered, many of the skeletons containing between the ribs their food, consisting of scales, and other remains of fishes, in an undigested state, it is inferred that they must have been suddenly destroyed, and entombed in the sediment in which they are now enveloped. We know that animals inhabiting waters are liable to immediate destruction, on these waters becoming adulterated by the intrusion of any foreign substance, the element being thus rendered unfit for respiration. In marine volcanic eruptions, in floods overwhelming rivers, and in every case where the water becomes adulterated with foreign matter, quantities of fish are found dead; we have, therefore, only to imagine a sudden admixture of so common a substance as mud or clay, to conceive that its intermixture would have been sufficient to destroy the then living inhabitants.

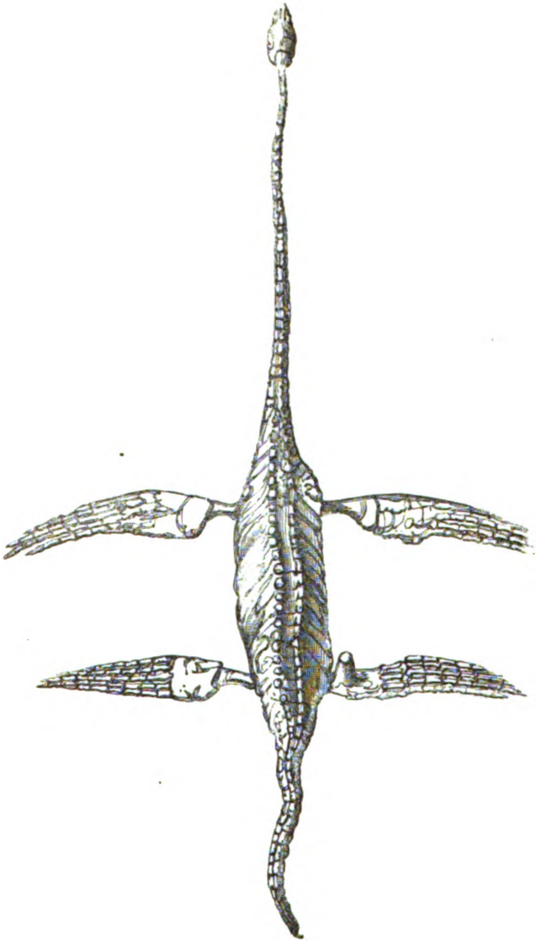


FIG. 245.—Plesiosaurus grandipinnis.

Origin of the Oolite and Lias.—That the ocean which deposited these strata was liable to sudden changes of the kind already mentioned, is conceived to be demonstrated by the varied nature of these beds, where argillaceous, arenaceous, and calcareous strata are found to succeed each other, the clay usually forming the substratum of the series. These alternations are accounted for on the supposition, that a sea, which during a certain period threw down deposits of clay, or mud, ceased to do so at a peculiar epoch, either from a change in its currents, or from the destruction or removal of the land, which had supplied the substance previously precipitated; under altered conditions the same waters might deposit beds of sand; or, finally, might afford conditions favourable for the growth of zoophytes, and thus produce those argillaceous, arenaceous, or calcareous deposits observable in different portions of this system.

EXERCISES

ON THE LIAS FORMATION.

1. Explain the meaning of the term lias.
2. Mention the chief authors and collections.
3. Name the distinctive features of the formation.
4. Mention the principal discoverers and collectors.
5. Describe the characteristic shells and fossils.
6. State the division of the beds.
7. Trace the geographical distribution of these deposits in this country and abroad.
8. Name the counties in which they occur in this country.

9. Point out any particular phenomena indicated by their organic remains.

10. Name the chief localities in which fossils have been discovered.

11. Mention the most recent discoveries effected in these deposits.

12. State any facts of general and instructive interest, and pursue the prescribed method of question and answer.

CHAPTER XVI.

NEW RED SANDSTONE SYSTEM.

NEW RED SANDSTONE; SALIFEROUS OR POIKILILIC* SYSTEM OF ENGLISH AUTHORS.

1.—RED OR VARIEGATED MARLS OF ENGLISH; MARNES IRISEES AND CALCAIRE CONCHYLIEN OF FRENCH; AND KEUPER AND MUSCHELKALK OF GERMAN AUTHORS.

2.—NEW RED AND VARIEGATED SANDSTONE OF ENGLISH; GRES BIGARRE OF FRENCH; AND BUNTER SANDSTEIN OF GERMAN AUTHORS.†

3. MAGNESIAN LIMESTONE OF ENGLISH; ZECHSTEIN OF GERMANS.

4.—LOWER NEW RED SANDSTONE OF ENGLISH; GRES DES VOSGES OF FRENCH; ROTHTODT-LIEGENDES OF GERMANS.†

THE ENTIRE FORMATION IS ALSO STYLED "TRIAS" IN GERMANY, BECAUSE IT THERE CONSISTS OF THREE PRINCIPAL PORTIONS; FIRST, THE VARIEGATED MARLS; SECONDLY, THE MUSCHELKALK; AND, THIRDLY, THE VARIEGATED SANDSTONE. THE MUSCHELKALK, THOUGH DISTINCTLY AND EXTENSIVELY DEVELOPED IN GERMANY, IS WANTING THROUGHOUT THE WHOLE OF FRANCE, WITH THE EXCEPTION OF THE ENVIRONS OF THE VOSGES MOUNTAINS, WHILE IN ENGLAND IT IS ABSENT ALTOGETHER.

* From ποικιλος, varied or mottled, from the appearance of these deposits.

† Of the German names above cited, the derivation of *Keuper*, which is supposed to be a miner's term, is wholly unknown. *Muschelkalk* is employed to designate a limestone containing *Mytili*. *Bunter Sandstein* or variegated sandstone is sufficiently clear. *Zechstein*, again, is obscure, but its derivation is referred by Adelung to the signification of *zech*, which means a company or association, who were accustomed to hire a pit or a quarry, for the purpose of working it, in this instance probably for copper. *Rothtodt-liegendes*, literally, *red-dead-lier*, is used to indicate that the copper found in the upper beds, has died out and is not met with in these underlying deposits.

MUSEUMS: GEOLOGICAL SOCIETY, THAT OF WARWICK AND OTHER LOCAL COLLECTIONS.

AUTHORS: MURCHISON, LYELL, SEDGWICK, JAEGER, VOLTZ, ELIE DE BEAUMONT, &c.

CHARACTERISTICS: A MARINE FORMATION COMPARATIVELY POOR IN FOSSILS; REMARKABLE FOR THE TRACES OF FOOTSTEPS OF ANIMALS; AND FOR ITS SPRINGS OF BRINE AND STORES OF ROCK-SALT, HENCE CALLED THE SALIFEROUS, AND ALSO FROM THE DIVERSIFIED TINTS OF THE STRATA, THE POIKILITIC OR VARIEGATED GROUP.

Beneath the lias occurs in the midland and western counties of England, a vast series of red marls and sandstones, which are succeeded by beds of limestone. The marl and sandstone beds are of varied tints, though a dull red derived from peroxyde of iron chiefly predominates. The name of *new*, is given to this system of deposits to distinguish them from the *old* red sandstone, which is often identical in mineral characters and usually lies beneath the coal, though in some local instances, in particular, the great coal-field of Dudley, the old red sandstone, usually ten thousand feet thick, is totally wanting, and the beds of coal repose on the underlying Silurian system.

The following table exhibits the distribution of these strata in the British localities in which they occur.

I. Upper new red sandstone or saliferous system.

Saliferous marls and sandstones.
Sandstone and quartoze conglomerate.

II. Lower new red sandstone.

Magnesian limestone.
Lower new red sandstone.

Geographical Distribution.—This system, like the last two series which we have described, traverses our island from south-west to north-east, and accompanies

the lias from the counties of Devonshire and Somersetshire, through the midland districts of Gloucestershire, Warwickshire, Lancashire, and Yorkshire, to Cumberland. It forms a region highly favoured by nature, though poor in fossil remains; containing rich stores of chemical substances, gypsum, soda and salt, within its own domains, and from immediately overlying the coal, presents at once such a stimulus and supply to energy and industry that, as Dr. Buckland has forcibly remarked, nineteen of our principal cities and chief seats of commerce from Exeter to Carlisle are all located on strata appertaining to this peculiar formation.

Deposits of this date and character are largely devoloped in France, Germany, Italy and European Russia, as well as in North America.

Rock-salt and Brine Springs. — We have mentioned, among the characteristics of this formation, its brine-springs and stores of salt, which constitute it the great source for supplying that essential substance, and entitle this series of deposits to the name of the saliferous group. The beds of new red sandstone which prevail in Cheshire, where the chief salt-works are established at Nantwich, and similar strata in Worcestershire, where the most important springs exist at Droitwich, yield an inexhaustible resource. There is historical evidence of their having been wrought by the Britons, and for 2000 years they have never ceased their unfailing supply. In the year 1725, it having been ascertained that the strata at Nantwich were perforated to a greater depth than was the case at Droitwich, the gypsum-beds of that place were broken through, when springs of much stronger brine poured into the pits, and by yielding a more valuable supply, greatly enhanced

the worth and productiveness of the works. The bed of gypsum, previously mentioned, lies about forty or fifty feet below the surface; it is a hundred and fifty feet thick, and on being perforated the stream of brine is reached, which is about two feet in depth and rests on a bed of rock-salt. The brine rises through the perforation, and is conveyed into iron boilers, for the purpose of evaporation and of producing the salt. The phenomenon of brine-springs is known to be produced by streams of water which have flowed over masses of rock-salt, but the production of rock-salt itself is by no means so easy of explanation. It constitutes, in fact, a problem which the present state of our knowledge by no means enables us to solve, and three distinct theories have been proposed to account for its origin: the first ascribing it to the evaporation of sea-water, and considering it to have been deposited in the bed of the sea; the second referring it to similar depositions from a salt-water lake, and the third attributing it with more probability to volcanic agency. The first two propositions are liable to the apparently fatal objections of the incalculable depth of water requisite for producing masses of rock-salt forty yards in thickness; as also the impossibility of such a cause being adequate to produce a mountain of salt six hundred feet in height, and twelve hundred in breadth at its base, such as is known to exist at Cardona in Spain. But, perhaps, the most conclusive proof in favour of the volcanic theory consists in the perfect freedom of the rock-salt from all extraneous matter; whereas it is conceived that had it been deposited by salt-water, it could not have failed to present some imbedded substances indicative of its sedimentary origin. The idea of its

having been produced by volcanic action is strengthened by the facts that chloride of sodium is of common occurrence among the ejections of volcanoes, and that salt-springs rise to the surface from the granite rocks themselves; whence it is inferred that the sources which supply the salt may lie as deep as those substances which yield the materials for modern lavas, and which have alike furnished the elements for the ancient trap-rocks and basalts in the early history of the earth.

Organic Remains of the Upper New Red Sandstone.—We have already mentioned that the dull red colour prevalent in strata of this formation is derived from oxide of iron, and it has been noticed as a striking fact, that all deposits in which this oxide prevails are extremely deficient in fossils; thus the new red sandstone exhibits a remarkable paucity of organic remains as contrasted with the oolite and lias. This circumstance is accounted for by the fact that the admixture is fatal to animal life, and that the metallic infusion acting on the *bronchiæ* or breathing processes of mollusca would cause such irritation of organs, so susceptible and delicate, as would speedily destroy the animals, and would thus account for their disappearance from strata of this peculiar chemical composition. In Germany, where this formation prevails, and where the *muschelkalk*, which is wanting in this country, is largely developed, the strata, especially the *muschelkalk*, are comparatively rich in organic remains. Of plants several *cycadeæ*, and various genera of ferns, together with a genus of *coniferæ*, termed *Voltzia*, and a genus of *equisetum* have been collected by Count Munster; of bivalve shells the *posidonia minuta*, and a species of *avicula* (*a. socialis*), and of the univalves some ammo-

nites, of the form called *ceratite*, have been discovered in these strata. It is however remarked, that the red sandstone strata are relatively deficient in fossils; and that organic remains chiefly occur in the argillaceous and calcareous beds of the system.

Fossil Footsteps.—But the impressions of footsteps of a peculiar character, occurring both in this country and in Germany, have formed the most interesting subject of inquiry which these deposits have recently afforded. Impressions of this nature had some time previously been observed in strata of this formation, in some quarries at the village of Hesseberg, near Hildburghausen, in Saxony, and were referred to a large unknown quadruped, which, from the obvious resemblance of the markings to the marking of a human hand, was provisionally named, by Professor Kaup, *cheirotherium*, or hand-beast, and was conceived by him to have been allied to the *marsupials*, since in the kangaroo the first toe of the fore-foot is set obliquely to the others, like a thumb.

The larger impressions, which seem to be those of the hind foot, are usually eight inches in length and five in breadth. At about an inch and a half before this impression a smaller print of a fore-foot, four inches long and three inches wide, occurs. The footsteps follow each other in pairs, each pair in the same line, at an interval of fourteen inches between each pair. Both the large and small steps show the great toe alternately on the right and left side; each step makes the print of five toes, the first or great toe being bent inwards like a thumb. Though the fore and hind feet differ so considerably in size, they are nearly similar in form.

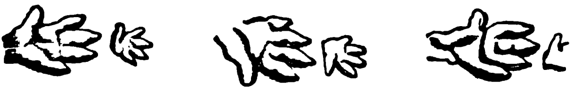


FIG. 246.

Some two or three years since, similar impressions were observed in strata of the same date and character in this country, namely, in five superimposed beds of clay, at the Storeton Quarries, on the Cheshire side the Mersey, opposite Liverpool, and which, like the vestiges previously discovered in Germany, were referred to the presumed marsupial animal above-mentioned. These mysterious vestiges exercised for some time the ingenuity of naturalists, and among other conclusions it was inferred that impressions of such depth and distinctness could only have been made by animals walking on dry land, as the weight of the creatures could not have been sufficient to cause them to sink so deeply in soft and yielding clay lying under water. It was farther conceived, that each layer of clay which bore these footsteps had been afterwards submerged, so that a new stratum was successively formed above the former, in a similar manner to that in which the ripple-marks in the sandstone of Cheshire and elsewhere are presumed to have been produced. Professor Owen, however, having directed his attention to these footsteps, and to the remains of reptiles, consisting of bones and teeth, which had been observed in beds of this character both in Germany and England, arrived at conclusions which, with the highest degree of probability, referred the impressions in question to an animal of a totally different

class. In two papers on the subject read before the Geological Society, Jan. 20, and Feb. 24, 1841, the Professor stated, among other particulars of interest, that he had ascertained, on a microscopic investigation of the teeth, that the genera *phytosaurus* and *mastodonsaurus* established by Dr. Jäger, on teeth of like character with these, are in fact one, the former having been founded on casts of the sockets of the former, while he showed that the latter generic appellation ought not to be retained; first, because it recals unavoidably the idea either of the mammalian genus mastodon, or of a mammilloid form of the tooth, whereas the teeth of the genus so designated are originally, and, for the greatest number permanently, of a cuspidate or pointed, and not of a mammilloid or rounded form; and next, because the second element of the word *saurus* indicates a false affinity, the remains belonging not to the saurian but to the batrachian order of reptiles, and attesting the former existence of frogs of gigantic dimensions in comparison with any now living. The fossil teeth both from England and Germany exhibited externally the usual reptile form and character, but internally they presented a most complicated texture, approaching that of the *ichthyosaurus*, yet differing from that and all other reptiles hitherto discovered, whether recent or extinct. As the texture of these teeth, under the microscope, presents a series of irregular folds, resembling the labyrinthic windings of the human brain, Professor Owen proposed the name of *labyrinthodon* for the genus.

The professor farther ascertained, from the examination of various bones, procured from the same formation, that he could determine three species of *labyrinthodon*,

and that in this genus the hind extremities were much larger than the fore. Hence the idea was first suggested that the tracks in question were those of the newly-found gigantic frog. It was farther observed, that the footmarks of the *cheirotherium* were more like those of toads than of any other living animal; and lastly, that the size of the three species of *labyrinthodon* corresponded with that of the three different kinds of footsteps, which had already been supposed to belong to three distinct individuals of *cheirotherium*. Finally, the structure of the nasal cavity showed the *labyrinthodon* to be an air-breathing reptile, since the posterior outlets were at the back part of the mouth, instead of being directly under the anterior or external nostrils. It must have respired free air, like the saurians, and may in all probability have imprinted on the shore those footsteps which, as before mentioned, were conceived to have been impressed by an animal walking on dry land.

In the second of the papers to which we have alluded, Mr. Owen stated, that from farther specimens which had been forwarded to him, by Dr. Lloyd, of Warwick, from the museum of that town, he had been enabled to determine two more species of *labyrinthodon*, five in all, to which he had applied the names—*l. salamandroides*, *l. leptognathus*, *l. pachygnathus*, *l. ventricosus*, *l. scutulatus*.

He farther mentioned, that he had long believed that the foot-prints were those of a batrachian, and most probably of that family which includes the toad and frog, on account of the difference of size in the fore and hind extremities, but that in consequence of the peculiarities of the impressions, he had always considered,

that the animal must have been quite distinct, in the form of its feet, from any known batrachian or other reptile; and thus in the *labyrinthodon*, he observes, we have a batrachian reptile, differing as remarkably from all known batrachia and from every other reptile in the form of its teeth.

MAGNESIAN LIMESTONE OR ZECHSTEIN.—The inferior members of the new red sandstone formation consist, in the south-west of England, of a conglomerate, formed of pebbles cemented together by a base of dolomite or magnesian limestone, whence it is termed dolomitic conglomerate. The imbedded fragments chiefly consist of *debris* of the rocks on which they repose, such as fragments of mountain-limestone, coal, shale, and other underlying deposits. In the north these conglomerates and breccias are represented by the magnesian limestone. This substance has lately been brought into use and repute for architectural purposes, buildings constructed of it having been ascertained to be extremely durable, and to have resisted for ages the attacks of time and of the weather. The stone is found, in fact, to combine the varied qualities so much desired by the architect, but so seldom found in the same material; uniting the softness and facility of working of the oolite above, with the hardness and compact texture of the more crystalline rocks below; while the magnesia which it contains is so unfavourable to vegetable growth as to check that minute vegetation which frequently disfigures the building-stones in general use. Qualities thus valuable induced the members of the commission for selecting stone for the new houses of Parliament, to give the preference to this material over all

others, which they had the opportunity of inspecting. It was remarked, that in this stone the carbonates of lime and of magnesia exist in nearly equal proportions. In many instances, this substance presents singular examples of spheroidal structure, induced, it is conceived, after the deposition of the stratified mass. Several beautiful and instructive specimens of this and other forms of this stone are deposited in the mineral collection of the British Museum (case 49).

ORGANIC REMAINS.—We have already had occasion to observe, that where certain strata resemble in mineral structure the beds above, the fossils which they contain often present an affinity to those of the deposits beneath, and in the present instance, those of the magnesian limestone partake rather of the types of the carboniferous system below, than of the new red sandstone above, the shells being of the genera *spirifer* and *producta;* while the fish are remarkable for that peculiarity of structure in the tail which is called by M. Agassiz the heterocercal, in which the tail is unequally lobed, as in the modern sturgeon and the shark, and the vertebral column runs along the upper lobe. On the other hand, the homocercal fish, comprising nearly all the living species, have the tail either single or equally divided, and the vertebral column not extended into the upper lobe.

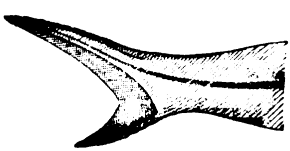


FIG. 247.—Heterocercal; Shark.

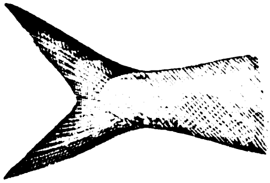


FIG. 248.—Homocercal; Herring.

On this peculiarity of the tail in the sturgeon and shark, Dr. Buckland remarks, that the prolongation of the vertebral column is calculated to sustain the body in an inclined position, with the head and mouth nearest to the bottom. Of the two fish above-named, he observes, that the former perform the office of scavengers, to clear the water of impurities, and adds, that they have no teeth, but feed by means of a soft leather-like mouth, capable of protrusion and retraction, on putrid animal and vegetable substances at the bottom; hence they have the same constant occasion to keep their bodies in the inclined position, as the extinct fossil fishes of this formation, whose small and numerous teeth shew that they also fed on like substances in similar situations. The sharks employ their tail in another peculiar manner to turn their body, in order to bring the mouth, which is placed beneath the head, into contact with their prey.

EXERCISES

ON THE NEW RED SANDSTONE FORMATION.

1. Describe the authors and collections.
2. Point out the general features of this system.

3. Mention its principal geographical distribution.

4. Trace its occurrence on the map.

5. Name the counties where it is developed.

6. State the division of the strata.

7. Mention their mineral composition.

8. Point out those which contain organic remains.

9. State the presumed cause of the paucity of fossil objects.

10. Mention the mineral resources of the strata.

11. State the localities of their occurrence.

12. Mention any general facts of interest or importance connected with these deposits, and the questions and answers illustrative of their history.

CHAPTER XVII.

THE CARBONIFEROUS SYSTEM.

COAL-MEASURES OF ENGLISH; TERRAIN HOUILLER OF FRENCH; KOHLENGEBILDE OF GERMAN AUTHORS.

MUSEUMS: BRITISH MUSEUM, GEOLOGICAL SOCIETY, THOSE OF NEWCASTLE, DUDLEY, LEEDS, HALIFAX, EDINBURGH, GLASGOW, DUBLIN, AND CABINETS OF MANY PRIVATE COLLECTORS.

AUTHORS:—BUCKLAND, LINDLEY AND HUTTON, ARTIS, WITHAM, PHILLIPS, MARTIN, PARKY, BRONGNIART, STERNBERG, PRESL, COTTA, CORDA, KNORR, SCHLOTHEIM.

CHARACTERISTICS:—A VAST AND PECULIAR SYSTEM OF DEPOSITS COMPOSED OF ALTERNATIONS OF MARINE AND FRESH WATER STRATA, BEDS OF IRONSTONE AND COAL, WITH SHALES, AND GRITS, CHIEFLY REMARKABLE FOR THEIR ABUNDANCE AND VARIETY OF FOSSIL PLANTS.

We have so often had occasion to allude to the coal formation, that a mere outline of its principal and characteristic features will suffice for the present description, and for more ample details we must refer to the various works of the authors above-mentioned, which treat at length of these highly interesting and important deposits.

The coal-fields of the British islands are extremely numerous, and the distribution of the beds varies of course according to local circumstances. The following will, however, be found to afford a general outline of their disposition and arrangement.

Coal-measures.

Strata of shale, sandstone, and grit, with occasional seams of coal and layers of iron-stone.

Mill-stone grit.

A coarse quartzose sandstone, passing into a conglomerate, sometimes used for millstones.

Carboniferous limestone, or mountain limestone.

A calcareous rock, containing marine shells and corals.

It will be seen that the coal forms but a relatively small part of the formation to which it gives its name, since it occurs in comparatively small seams, amid masses of rock, of far greater size and extent.

In addition to the remarks already suggested on the importance of the coal, we would repeat, that its value, in this country, is enhanced, to an incalculable extent, by its association with the beds of iron-ore occurring in the contiguous shales; while these again could not be fused without the aid of the mountain-limestone, which acts as a flux, and promotes the speedy reduction of the ore. In other countries, where the beds of coal are not accompanied by deposits of so much value, as in Silesia, where they are associated with rocks of older date, and in various parts of France, where the coal is similarly situated, its value is restricted to its mere employment as fuel, and these communities are thus destitute of the commercial advantages which its favourable distribution in our own islands enables us to enjoy.

The Coal-fields of England and Wales.—These are arranged, by Conybeare and Phillips, into

I. The coal-fields north of the Trent, comprising those of

1. Northumberland and Durham.

2. Yorkshire, Nottinghamshire, and Derbyshire.

3. North Staffordshire, sometimes called the Pottery coal-field.

4. Manchester.

5. Whitehaven.

II. The Central coal-fields, including those of

1. Leicestershire.

2. North Staffordshire.

III. The Western, divided into

1. The north-western, containing those of North Wales.

2. The western, comprising those of the Plain of Shrewsbury; of Coalbrook Dale and the Clee Hills.

3. The south-western, comprising the coal-fields of South Wales, of the Forest of Dean, and those of Gloucestershire and Somersetshire.

Mr. Sopwith has executed some beautiful models, which exhibit, in the most instructive manner, the stratification of the coal, and the accompanying deposits; and has thus depicted the coal-measures of the forest of Dean, by means of sliding tables, which display the amount of coal, both wrought and unwrought, as well as of the iron-stone which accompanies it. These models may be procured of Mr. Tennant, No. 149, Strand.

Coal also exists in France, the Netherlands, the banks of the Rhine, in Saxony and Bohemia, in Sweden and Russia, in Persia, China and Hindostan, in North and South America, and Australia.

Igneous Rocks.—These are frequent in the carboniferous series of this country, occurring as overlying stratiform masses alternating with sedimentary deposits; but more frequently as dikes, which have penetrated

through the strata. In England, the principal intrusions of these rocks are presented by the green-stone and basalt, or whinstone, as it is locally termed, of the North of England; the toad-stone of Derbyshire, so called from its mottled appearance; and the basaltic masses of the South Staffordshire or Dudley coal-field. They present the effects usually observed at the point of contact of rocks of this character with sedimentary deposits, especially that of hardening and crystallizing them; converting shale into slate, charring coal to coke, anthracite, and plumbago; and inducing crystalline texture in limestones and calcareous rocks.

VEGETABLE ORIGIN OF COAL.—The origin of this substance is now universally admitted, and no doubt exists, that it is so much vegetable matter altered by heat and pressure; that it consists, in short, of the vegetation of the ancient earth which has been buried beneath waters, and has either been submerged on the very place of its growth, or conveyed to estuaries or the mouths of rivers, and sunk in spots alternately occupied by fresh and salt waters, where, under the heat generated by moisture, and the pressure of the slime, mud, sand, or clay deposited by these streams, the vegetable masses have been elaborated into coal. The agency by which this result has been effected is considered to have been analogous to that by which, under similar circumstances of moisture and pressure, vegetable matter is known to ferment, to produce spontaneous combustion, and to be consumed. For instance, if hay be stacked in a moist condition, or too closely packed, fermentation and ignition are produced, and the mass is consumed; if the process be interrupted and combustion prevented, the hay is found to have

acquired a dark brown colour, a glazed or oily surface, and a bituminous odour. The same phenomena are observed in the case of flax, which if packed and pressed in a damp state, is liable to the same results; all vegetable substances, in short, being exposed to similar consequences, and what is termed spontaneous combustion being often produced from like causes. Were any vegetable matter in a moistened condition placed beneath great pressure, so as to prevent its gaseous principles from escaping, bitumen, lignite or coal would be produced, according to the various stages of the progress. Vegetable matter has been traced through every stage of the saccharine, vinous, acetous, and bituminous fermentation; and alcohol, ether, naphtha, petroleum, bitumen, lignite, jet, coal, amber, and even the diamond, have been ascertained to be of vegetable origin. It has been suggested that the rarity of the diamond need not excite surprise, when we reflect how rarely we meet with iron in its native state, in comparison with the various combinations which that substance presents with other elementary bodies.

Experiments of Göppert. — The experiments of Professor Göppert, of Breslau, which have been followed in this country, would alone be sufficient to establish the vegetable origin of coal, even if it were not already proved beyond the possibility of doubt. This *savant* endeavoured to imitate the agency of nature in this phenomenon, and, as was evinced by the result, with perfect success. Having observed that the leaf, in iron-stone nodules, might occasionally be separated, in the form of a carbonaceous film, he placed fern-leaves in clay, dried them in the shade, exposed them to a red heat, and thus obtained striking resemblances to

fossil plants. According to the degree of heat, the plant was found to have become either brown, shining, black, or to be entirely lost, the impression only remaining; but in this latter case, the surrounding clay was stained black, thus indicating that the colour of the coal-shales is derived from the carbon of the plants which they include.

Mode of Deposit of Coal.—Yet though the vegetable origin of coal is thus universally admitted, a considerable difference of opinion still prevails as to the circumstances under which it has become imbedded in its present position. The idea usually entertained has been, as before stated, that groves and forests of the luxuriant vegetation of an ultra-tropical climate have been swept away by floods and inundations into lakes, bays, estuaries, or mouths of rivers, and spots alternately filled by fresh and salt waters; while the instances it was conceived were few, in which the coal grew and was submerged on the spot in which it now occurs: in short, it was considered, that drift was the rule and submergence the exception. An opinion the very reverse of this, however, has recently been expressed, and the attention of the author of these pages having been drawn to the subject, he has no hesitation in avowing his adhesion to the new theory, and his conviction that while the greater part of the coal has grown and been imbedded on the spot, the cases where it has been drifted are chiefly the accidental results of the overflows and inundations by which the submersion was effected. The objections applying to the idea that coal was formed by drift, and which appear to offer almost insurmountable difficulties to such a supposition, are as follows:

1. The purity of the coal and its freedom from extraneous substances. It is contended, with every appear-

ance of probability that had the coal been drifted in the manner conceived, it must infallibly have acquired some portion of foreign substances in its transit; such as pebbles, gravel, &c.; but, since we find extensive seams of coal utterly unmixed with any other matters, its freedom from these is considered to be incompatible with the idea of its having been wafted from a distance.

2. The generally uniform thickness of each coal-seam is considered to offer another difficulty. The lower main seam of the great northern coal-field is mentioned by the late Mr. Bowman as extending over at least 200 square miles, while a thin seam is pointed out as reaching in a straight line from Whaley Bridge to Blackburn, a space of thirty-five miles. Had the coal been washed away by floods or torrents in the manner conceived, it is argued that such currents, either from the different specific gravity of portions of the same mass, of the roots and stems, for example, as contrasted with the branches and foliage, or from the mechanical obstructions occurring in such a transit, would have deposited their burthen, in an extremely unequal manner, in heaps and hillocks; whereas, no such effects are observable in the coal-seams, which are invariably free from all inequalities of this kind.

3. The exceeding minuteness of many of the seams of coal, which thin out into mere filaments, and yet extend, in this condition, over extensive areas of solid rock, is alike conceived to militate against the idea of any deposits of so attenuated a nature having been spread over spaces so large by the action of drifting.

4. On the other hand, the size of many of the coal-seams, considered with reference to the immense compression which they have unquestionably undergone, is considered to furnish another objection of insurmountable

character. The enormous extent to which the bulk of substances may be reduced by pressure, is scarcely to be conceived, except by a reference to exact computation. For instance, we are indebted to Mr. Burr for the fact, that a mass of rubbish which was left in a worn-out vein of iron-stone, during a period of only two years, was in that interval reduced from seven to no more than two feet in thickness, owing to the pressure of the overlying weight. It was farther formed into so hard a substance, as to present one mass of rock, which could only be penetrated by the operation of blasting. Now when we consider, first, the far greater compressibility of vegetable matter than of mineral detritus; when we reflect that the beds of coal have been subject to the pressure of masses, not of a few yards, but, in numerous instances, of many thousand feet in thickness, and this during a period not of a couple of years, but during the countless ages of the past; and when we call to mind that matter so compressed has formed, by the meeting of several seams, beds of great relative thickness—in the Staffordshire coal-field, for example, of thirty feet in depth, it will be self-evident that for the formation of such deposits supplies on the most enormous scale would be required, and that it would be utterly impossible to transport, by the action of water, masses of vegetable substance so immense as would be requisite for the formation of this deposit alone of the coal.

5. The high state of preservation in which many of these objects occur, the perfect condition of the leaves, and parts of fructification of many of the ferns, the sharp angles of numerous stems of plants which are presumed to be of soft and succulent nature, with the surfaces of *sigillariæ* marked with lines, streaks, and flutings, so delicate, it has been observed, that the mere drifting of

a day would have inevitably destroyed them, together with the occurrence of fruits, such as *cardiocarpon* and *lepidostrobus*, which are found in heaps and clusters, whereas a current would have dispersed them,—these, with facts of like nature, and leading to similar conclusions, convince us that these objects have never been subjected to drift, but are buried on the spots where they lived and flourished.

6. An additional objection to the drift theory has been founded on the chemical condition of the question; and it has been urged, with every appearance of truth, that if vegetable matter were swept away by a flood, such an agency, by allowing the gaseous particles to escape, would never be adequate to produce the desired results, and that coal never could be formed by such a process. The very close analogy presented by peat to lignite and coal affords a striking corroboration of the justice of such a view.

7. The multiplied instances of trees found erect on the spot where they unquestionably grew, is considered to overthrow the idea of transport altogether, and to establish the fact of the coal having chiefly grown on the spot where it is now entombed. Not only has Mr. Hawkshaw discovered the group of trees already mentioned on the line of the Bolton and Manchester Railway, but Mr. Conway has stated that on forming the railway tunnel at Claycross, five miles south of Chesterfield, a number of fossil trees, apparently *sigillariæ*, no fewer than forty, standing not less than three or four feet apart, and forming in short a perfect fossil forest, were discovered. And when we reflect on the merely accidental nature of these discoveries, that they are made by chance in cuttings and excavations of limited nature and extent, it is impossible to resist the convic-

tion thus enforced on the mind, that the earth contains innumerable forests entombed on the spots where they grew, many of which the progress of research and discovery will probably bring to light.

The idea of the submergence of coal is, in fact, no new supposition. Similar opinions have been expressed by Count Sternberg, by Adolphe Brongniart, and the authors of the Fossil Flora, and have recently been repeated by Mr. Hawkshaw, Mr. Bowman, Mr. Logan, Mr. Ick and others.

Mr. Logan,* in a highly interesting communication on the coal strata of South Wales, mentions that there is no instance in that extensive carboniferous district of any seam of coal without a bed of underclay abounding in *stigmaria ficoides*, the marshy plant above mentioned, which exists in such extent and abundance as to have formed, as he conceives, the chief source of our vast supplies of fossil fuel. In a second communication made on the 23rd of March of the past year, on the coal-fields of Pennsylvania, he states the same phenomenon of the underclay to prevail throughout those deposits.

So much light has thus been thrown on the formation of coal by these and similar observations, that an opinion now prevails which is in substance as follows. It is conceived that the vegetation which produced the coal grew in broad and shallow lagoons and sheets of water, receiving at intervals deposits of silt and mud, the detritus of neighbouring land, and situate on an island or a sea-shore. These streams were speedily filled up by the growth of a profusion of *stigmariæ*, which have already been mentioned as a marshy, succulent plant, until, by the accumulation of mud, silt,

* See Proceedings of Geol. Soc., vol. iii. No. 69, p. 275.

sand, and the admixture of decayed vegetable matter, the lagoon was converted to a morass. A fresh vegetable growth now ensued, of somewhat different character, consisting of reed-like plants, *equiseta* and *calamites*, with here and there a larger tree. The spoils of these plants may thus have furnished materials for beds of peat and coal, resting on a base composed exclusively of the remains of *stigmariæ.* These spots may, by repeated subsidences, have been so reduced beneath the level of the sea, as to have rendered them the receptacles of alternating deposits of sand and clay, and may thus have produced the strata of sandstone and limestone which occur between seams of coal. As each deposit was formed, it may have been covered either wholly or in part by a lagoon, when the same succession of vegetable growth and geological deposit may have ensued, and fresh supplies of mineral fuel may have been produced.

The alternation of beds of coal with marine deposits is explained by the supposition that extensive subsidences of the estuaries, which were the site of the lacustrine and terrestrial vegetation above described, may have reduced these estuaries beneath the level of the sea, where the submerged soil with its vegetation was covered with accumulations of encrinital limestone, and other marine sediments; and that in course of time, either by drifts of sand or clay from the land, or by the elevation of the bed of the sea, the estuaries were again filled, and became the area of the vegetable growth above named, while the repetition of such changes would account for the alternations of marine and vegetable deposits which occur in our beds of coal. The annexed engraving, depicting a virgin forest of the isle of Gouahan, one of the Mariana islands, depicts the character of vegetation which is conceived to have produced the coal.

FIG. 249.

Erect Fossil Trees.—These have been found in various parts of the continent as well as of this country.

At St. Etienne, near Lyons, a whole bed of them appears in a nearly horizontal position.

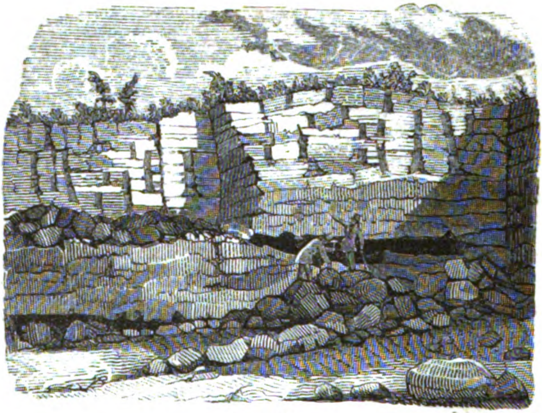


FIG. 250.

A single tree was brought to light some years since, at the Craig Leith Quarry, near Edinburgh.

FIG. 251.

Those discovered by Mr. Hawkshaw are here figured.

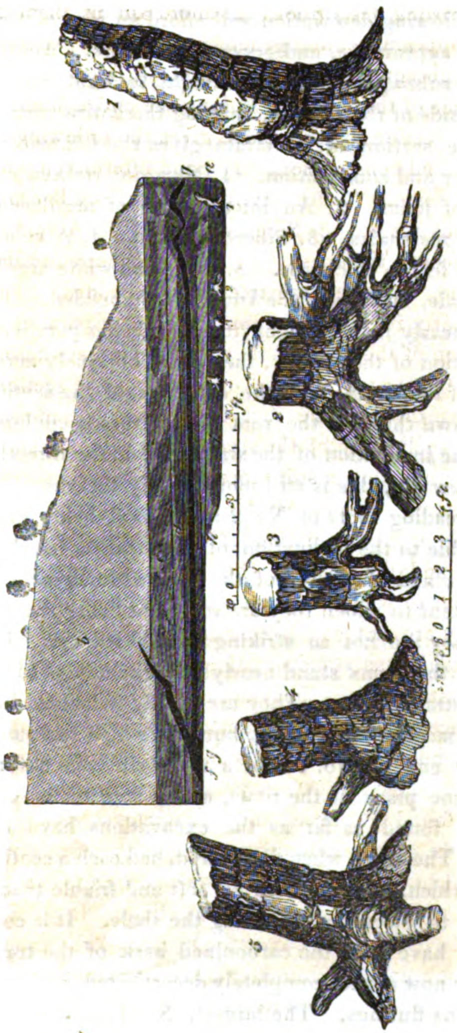


FIG. 252.—Erect Fossil Trees, on Bolton and Manchester Railway. *a* The trees. *b*. Stratification above the fossils of sand intermixed with patches of loam. *c*. *d*. & *e*. Consisting of thin beds of shale. *f*. A fault filled with shale. *g*. A seam of coal, two feet in thickness.

The following description will afford an idea of their position, appearance, and general characters. Another tree has subsequently been brought to light on the opposite side of the railway, making the entire number six. The section of the strata gives the following as their order and composition. 1. Sand intermixed with patches of loam. 2. An intermixture of argillaceous and siliceous shales. 3. Siliceous shale. 4. A vein of coal, two feet in thickness. 5. Blue and white argillaceous shale, in which the trees are imbedded. The five are nearly in a straight line, and being parallel to the direction of the railway, they stand obliquely across the dip of the strata. In the direction of the section, a line drawn through the root of the trees is conformable to the inclination of the strata, and in the direction of the new dip, this is still more plainly the case; the large spreading roots of No. 2 and No. 5, being quite conformable to the inclination of the stratum in which they rest; and the roots of the others are equally so, to the extent to which they are seen, but being less exposed, they are not so striking in this respect. The whole of the stems stand nearly at right angles to the plane of stratification. They are chiefly imbedded in a soft, argillaceous, blue shale, but that which surrounds the upper end of No. 1 is of a more siliceous nature. In the same plane as the roots, a thin stratum of coal has been found as far as the excavations have extended. The trees, when discovered, had each a coating of coal, which, however, was so soft and friable that it crumbled to pieces in removing the shale. It is conceived to have been the carbonized bark of the trees, since they now appear completely decorticated, and present various flutings. The largest, No. 1, is about fif-

teen feet in circumference at its base; seven feet and a half at its top, and eleven feet in height. The next, No. 5, is seven feet and a half in circumference, and two feet and a half in height; while Nos. 3 and 4 are of smaller size, being respectively three and five feet in height, and six in circumference.

EXERCISES

ON THE CARBONIFEROUS SYSTEM.

1. Name the authors and collections.
2. Mention the chief characteristics of the system.
3. State the usual arrangement of the beds.
4. Describe the chief coal-fields of England.
5. Explain the origin of coal.
6. Describe its deposition by subsidence, and state the reasons for ascribing it to this agency, rather than to drift.
7. Explain the nature of its vegetation.
8. Describe the character of its climate.
9. State any general phenomena, and pursue the accustomed method of question and answer.

CHAPTER XVIII.

THE MOUNTAIN LIMESTONE.

THE CARBONIFEROUS OR MOUNTAIN LIMESTONE OF ENGLISH; CALCAIRE CARBONIFERE, CALCAIRE ANTHRACIFERE, CALCAIRE DE TRANSITION OF FRENCH AUTHORS.

MUSEUM:—GEOLOGICAL SOCIETY; BRISTOL, YORK, AND DUDLEY INSTITUTIONS; COLLECTION OF MR. GILBERTSON, NOW TRANSFERRED TO THE BRITISH MUSEUM; THAT OF DUBLIN, &c.

AUTHORS:—MARTIN, MILLER, SEDGWICK, PHILLIPS.

CHARACTERISTICS:—A MARINE DEPOSIT ABOUNDING IN ZOOPHYTES, (CHIEFLY CRINOIDEA,) SHELLS, FISH, AND OTHER MARINE EXUVIÆ, REMARKABLE FOR THE ABUNDANCE AND VARIETY OF ITS MINERAL PRODUCTIONS, ITS CAVERNS, AND FISSURES.

THE practice of bestowing new names on objects familiar to science, is neither commendable in itself, nor in a general way calculated to prove permanent or successful; yet the formation we are about to describe really seems to require some more appropriate appellation than those which are cited above, and by which it is usually distinguished. The term carboniferous properly signifies bearing or producing coal, whereas this limestone, with perhaps the single exception of the Berwickshire coal-field, never contains that substance; while the name mountain-limestone is equally ill bestowed on deposits, which, both in this country, Ireland, and on the continent, frequently occupy valleys and low grounds.

GEOGRAPHICAL DISTRIBUTION.—It is extensively de-

veloped over the northern and western parts of England, in Derbyshire, Shropshire, Somersetshire, and Gloucestershire, lying between the coal and the more ancient rocks beneath. In Cumberland and Westmoreland it obtains considerable elevation, partly encircling the mountains of slaty rocks; while in Derbyshire it rises to independent peaks and hills, presenting scenery of the wildest and most picturesque character.

MINERAL PRODUCTIONS.—These are more abundant in this formation than in any hitherto described. The rock itself is of sub-crystalline texture, is susceptible of a high degree of polish, and from its embedded coral remains presents specimens of exceeding beauty and interest. We have already noticed the fact, that many marbles of this locality, as well as of Staffordshire and of Devon, are as splendid as those of Italy; and owing to the prejudice in favour of every thing foreign are frequently sold as such. The British Museum contains some splendid polished slabs exhibiting admirable examples of the structure of the *crinoidea*. Fluor-spar occurs abundantly in veins in the vicinity of Castleton, and the manufacture of this substance into objects of ornament, cups, vases, &c., constitutes a local branch of industry of considerable importance. Manganese, copper, zinc, barytes, and iron also exist in this deposit; but the most abundant ore is the sulphuret of lead or galena, of which there are several extensive mines.

ORGANIC REMAINS.—These consist of abundance of corals, chiefly of those classes which form the coral reefs now in course of formation: there are also great numbers of crinoidea, of which this deposit may be considered to constitute the principal habitation. Of the conchiferous mollusca the prevailing genera are *spirifer*

and *producta* (leptæna). Of cephalopoda, the prevalent forms are the *orthoceras*, *bellerophon*, *goniatite*, *ammonite*, and *nautilus*. The first two are not found higher than the carboniferous deposits. The *orthoceras* was a chambered and siphuncled shell, like a *nautilus*, uncoiled and straight: the *bellerophon* was unchambered: the *goniatites* were a section of ammonites, having the lobes and septa free from denticulations. The *euomphalus* is another extinct genus of spiral univalves, which is extremely abundant in this limestone. The interior is often divided into chambers, but the partitions of these chambers are not perforated as in foraminiferous shells, or in those which have siphuncles, as the nautilus. The illustration below depicts several of the forms of shells characteristic of this formation.

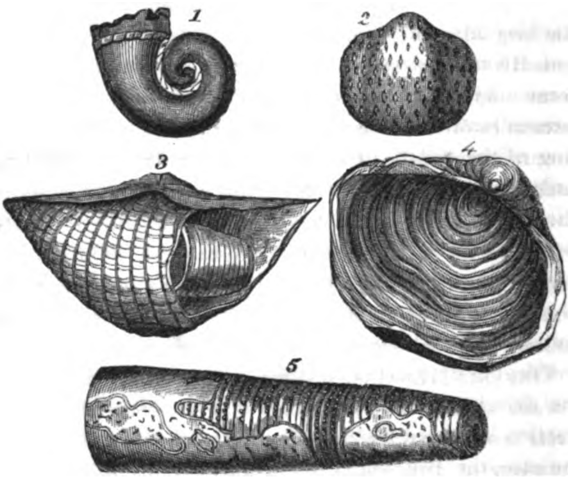


FIG. 253.—Bellerophon cornu-arietis. 2. Producta (leptæna) scabricula. 3. Spirifera trigonalis. 4. Producta (leptæna) punctata. 5. Orthoceras undatum.

CAVERNS.—This system of deposits is alike distinguished for the extensive caverns which prevail in the strata, as, for example, those of the Peak and other caves of Derbyshire, as well as of Devon and various parts of Ireland, where the formation is developed. Many of these are the channels of subterranean rivers and streams, conducted into them through fissures, which are very abundant, and which receive not only the water which falls from the atmosphere, but also many of those streams, which having their rise in other strata, flow into these deposits.

These caverns are also remarkable for the *stalactites* and *stalagmites* which they so abundantly present. The explanation of these phenomena is, in brief, as follows. Water which flows through limestone rocks has the power of dissolving a portion of the limestone, and on reaching any opening, such as a cavern, at its sides or roof, it forms a drop, the moisture of which is soon evaporated by the air, leaving a small circular plate of calcareous matter, which is increased by the constant dropping of the water. In process of time continual accumulations of this nature form long pendent points like *icicles;* for a *stalactite* may be said to be an *icicle* of stone, as an *icicle* may be said to be a *stalactite* of frozen water. When the supply of water holding lime in solution is too rapid to allow its evaporation at the bottom of the *stalactite*, it drops to the floor of the cave, and drying up, gradually forms in like manner a *stalactite* rising from the ground, which for the sake of distinction is termed a *stalagmite*. Where, as is frequently the case, the two unite, they form natural columns of the most picturesque beauty and effect. The most celebrated caves of this nature consist of the Grotto of

Antiparos, in Greece; that of Adelsberg, in Styria; and Weyer's cave, in the United States.

TABLE FORMED OF STALAGMITE.—Among the treasures of the British Museum, is a splendid table formed by the process above described. In a lead mine in Derbyshire appertaining to this formation, and situated on the estates of his Grace the Duke of Rutland, a square wooden pipe, which was employed to carry off the water, was found to be choked up, and on inspection proved to be completely occupied by a deposit of limestone, formed by the water in flowing through the pipe. A very curious instance of the plastic power of nature, analogous to that remarked under other circumstances, was also observed. There are certain multivalve shells, the *balani*, which attach themselves to rocks, and at the point of junction the attached valve is found to assume the very nature of the rock to which it adheres. Thus, in this singular object, so exactly has the stone, as it has been deposited, molecule by molecule, assumed the character of the wood on which it has been formed, with its grain, knots, stains, and markings, as to render it impossible to ascertain the difference by the eye, and it is only by the actual touch that we can determine it to be really stone, and not the wood to which it presents so perfect a resemblance. Portions of these slabs were formed into a table, and presented by the Duke of Rutland to the British Museum, where the object excites the admiration of all visitors to whom its remarkable history and origin are explained. A similar table adorns the baronial hall of Belvoir Castle.

EXERCISES

ON THE CARBONIFEROUS, OR MOUNTAIN LIMESTONE.

1. State the characteristics of the formation.
2. Point out its geographical distribution.
3. Trace its course on the map.
4. Name the localities in which it prevails.
5. Describe its organic remains.
6. Mention its mineral contents.
7. State any facts of general interest, and pursue the method of question and reply as before.

CHAPTER XIX.

THE OLD RED SANDSTONE.

OLD RED SANDSTONE, OR DEVONIAN SYSTEM, OF ENGLISH AUTHORS; GRES ROUGE INTERMEDIATE, OF FRENCH; GRAUWACKEN-GEBILDE OF GERMAN AUTHORS.

MUSEUMS:—GEOLOGICAL SOCIETY, VARIOUS COLLECTIONS IN SCOTLAND.

AUTHORS:—HUGH MILLER, MURCHISON, SEDGWICK, BOUE.

CHARACTERISTICS: A MARINE DEPOSIT, CHIEFLY REMARKABLE FOR ITS EXTRAORDINARY FORMS OF FOSSIL FISH.

THIS peculiar formation affords a striking and instructive example of the progressive nature of geological enquiry, and of the inexhaustible variety and extent of the phenomena of nature. Up to a recent period, the old red sandstone was regarded merely as a subordinate member of the carboniferous series, and from its supposed paucity of fossils, and of any objects of striking interest, was usually passed over in silence and neglect.

Owing, however, to the researches of modern geologists, and in particular of that distinguished observer by whom the Silurian beds have been raised to the rank of a distinct formation, the old red sandstone group has been raised to a like independent station, and has been found, on examination, to be replete with organic remains, affording phenomena of the highest interest.

Distribution of the Strata.—Mr. Murchison, in describing the series, has adopted the triple division, proposed many years since by Dr. Buckland and Mr. Conybeare.

1. A quartzose conglomerate passing downwards into chocolate, red, and green sandstone and marl.
2. Cornstone and marl, (red and green argillaceous spotted marls,) with irregular courses of impure concretionary limestone, provincially called cornstone, mottled red, and green; containing remains of fishes.
3. Tilestones, finely laminated hard reddish or green micaceous or quartzose sandstones, which split into tiles, containing remains of mollusca and fishes.

The thickness is estimated on an average at 10,000 feet, but in various localities in Scotland it is conceived to be much greater.

In England this formation is largely developed in the south of Devon, in Shropshire, Herefordshire, and the border-counties of Wales, and still more extensively in the North of Scotland; while on the continent, it occurs in Germany, and over vast areas in Russia, south of St. Petersburgh.

Identity of the old red Sandstone of Hereford and Devon.—Doubts were entertained for a considerable period as to whether the red sandstone of Devon and that of Herefordshire were identical; these doubts being chiefly suggested by the discrepancy, that the strata of Devon presented shells, chiefly of the genera *orthis*, *spirifer*, *productus*, *terebratula*, &c., which were not discoverable in the rocks of Herefordshire; which, on the other hand, though destitute of shells, afforded fish, which were not found in those of Devon. Mr. Murchison, however, in his first visit to Russia, in 1840, succeeded in discovering in deposits appertaining

to the old red sandstone the fish of Herefordshire and Scotland, in the same beds with the shells of Devonshire. Hence the strata of Devon and of Hereford are now recognized as identical, and have been raised to the rank of an independent formation, under the name of the Devonian system. Mr. Murchison and Professor Sedgwick have farther shown, that equivalents of the Devonshire rocks exist in the Rhenish provinces, and adjacent parts of Germany. Certain species of corals of the genera *cyathophyllum* and *porites*, *c. cæspitosum*, and *c. pyriforme*, with the shells *calceola sandalina*, and *terebratula porrecta* of Sowerby, are considered as characteristic of the rocks of Devon.

This system is more largely developed in Scotland, where it extends over a considerable portion of the northern part of that kingdom. The formation, as occurring in Scotland has been described with so much ability and eloquence by the Scottish historian of this deposit, that we must refer to the graphic and highly interesting publication of Mr. Hugh Miller, "On the Old Red Sandstone," which combines the instruction of a work of science with the fascination of a romance, and the ability of a writer of the very highest genius.

Fossil Fishes of this Formation.—It may be sufficient for our present purpose to state, that the three subdivisions of the formation are extensively developed in Scotland, its most prevalent and important fossil remains consisting of *ichthyolites*, or fossil fish, some of which are of the same genera as those discovered in Herefordshire, viz.: the *holoptychius*, and the *cephalaspis*; while others belong to the new genera *pterichthys*, *coccosteus*, *diplopterus*, *dipterus*, *cheiracanthus*, &c. &c.

Six species of the *pterichthys* (or winged fish) are

mentioned by Mr. Miller. The accompanying figure represents the under-surface of one of these.

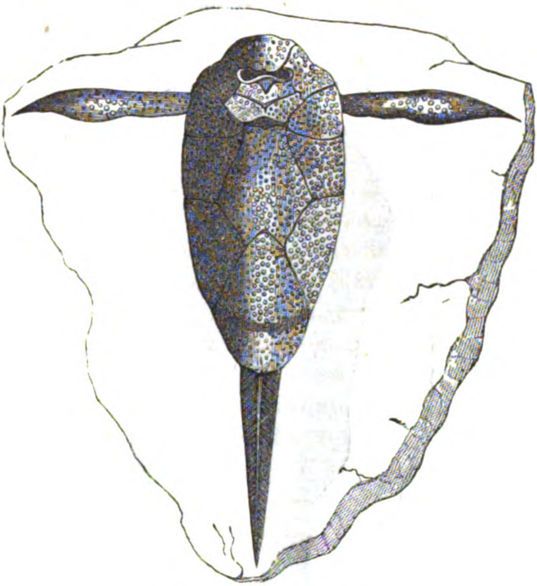


FIG. 254.—Pterichthys.

Mr. Miller mentions his first impression to have been, that the singular wings or arms, with their strong points and oar-like blades, had been at once paddles and spears, instruments of motion and weapons of defence; but he adds: "I was informed by Agassiz, that they were weapons of defence only, which, like the occipital spines of the river bull-head fish, were erected in moments of danger or alarm, and at others, lay close to the creature's side, and that the sole instrument of motion was the tail."

The genera *dipterus* and *diplopterus* are thus named,

because their two dorsal fins are so placed as to front the anal and ventral fins, and thus appear like two pairs of wings. The succeeding figure represents the *co ccosteus*,

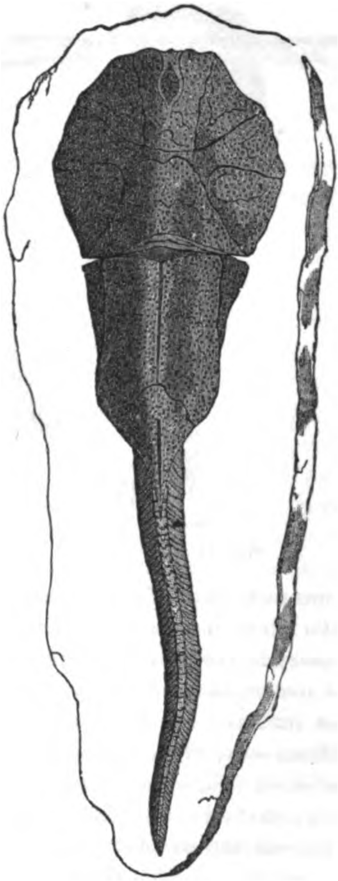


FIG. 255.—Coccosteus.

a singular peculiarity of which consists in the circumstance, that it is the only known animal of the vertebrated class which has a mouth opening in a vertical direction similar to that of the *crustacea*, that of all other *vertebrata* opening in a horizontal direction. For the highly graphic description of this animal, as well as of its congener the *pterichthys*; for numberless objects of like interest; and in short for the general history of this singular system of deposits, we must again refer to one of the most delightful books ever written, that of the able and interesting historian of the old red sandstone.

EXERCISES

ON THE OLD RED SANDSTONE FORMATION.

1. Describe the authors and collections.
2. State the general characteristics.
3. Mention its geographical distribution.
4. Describe its organic remains, and follow the usual method of question and reply.

CHAPTER XX.

SILURIAN SYSTEM.

SILURIAN SYSTEM OF MR. MURCHISON AND ENGLISH AUTHORS; SYSTÊMES QUARTZO-SCHISTEUX SUPÉRIEURS ET INFÉRIEURS OF M. DUMONT; PALÆOZIC ROCKS OF AUTHORS.

MUSEUMS: GEOLOGICAL SOCIETY; MUSEUMS OF DUDLEY, LUDLOW, &c.; COLLECTION OF R. I. MURCHISON, ESQ., AND OF VARIOUS LOCAL COLLECTORS.

AUTHOR: MURCHISON.

CHARACTERISTICS: A MARINE DEPOSIT OF VAST EXTENT AND IMPORTANCE, CONTAINING A GREAT ABUNDANCE AND VARIETY OF MARINE ORGANIC REMAINS.

THIS system of deposits, which was formerly imperfectly known, and was classed under the general and vague denomination of grey-wacke or transition-rocks, has been most ably and amply investigated by Mr. Murchison, to whose splendid work on the subject we must refer for more complete details. The name of Silurian has been bestowed on them, by the above distinguished historian of this interesting geological region, in consequence of the districts which they occupy in this country being those formerly inhabited by that tribe of the ancient Britons named the Silures.

GEOGRAPHICAL DISTRIBUTION.—They extend from the heart of South Wales to that of England, over the counties of Radnor, Montgomery, Caernarthen, Brecon,

Pembroke, and Monmouth; Gloucestershire, Worcestershire, Shropshire, and Herefordshire.

They are classified by their zealous and able investigator into the two divisions of Upper and Lower, which are again subdivided into three upper and two lower groups.

UPPER SILURIAN ROCKS.

1. Ludlow formation.	1. Upper Ludlow.	Micaceous grey sandstone.	Containing shells of every order, brachiopoda most abundant, corals and sauroid fish. Thickness 2000 feet.
	2. Aymestry limestone.	Argillaceous limestone.	
	3. Lower Ludlow.	Strata with concretionary limestone.	
2. Wenlock formation.	1. Wenlock limestone.	Concretionary limestone.	Shells as before, trilobites. Thickness 1800 feet.
	2. Wenlock shale.	Argillaceous shale.	

LOWER SILURIAN ROCKS.

3. Caradoc formation.	Caradoc sandstones.	Flags of shelly limestone and sandstone with white freestone.	Crinoidea, corals, mollusca, chiefly brachiopoda, trilobites. Thickness 2500 feet.
Llandeilo formation.	Llandeilo flags.	Dark coloured calcareous flags.	Mollusca and trilobites. Thickness 1200 feet.

I.—Upper Silurian Rocks.—The first member of the upper series consists of the Upper Ludlow, which is a grey calcareous sandstone containing spines, scales and teeth of fish peculiar to this formation, of the genera *sphagodus*, *pterygotus*, *plectrodus*, *sclerodus*, *thelodus*, and *onchus*, which are admirably described and splendidly figured in the work of Mr. Murchison. The shells present specimens of *avicula*, *cypricardia*, and those shells which, formerly termed *producta* and *spirifer*, as has been mentioned in our chapter on conchology, have recently been named *leptæna*, *atrypa*, and *orthis*.

A peculiar form of trilobite, in which the divisions of the dorsal carapace are almost obliterated and the back is nearly smooth, is characteristic of the upper Silurian beds, and from its peculiar smoothness has been named by Mr. König *homalonotus*.

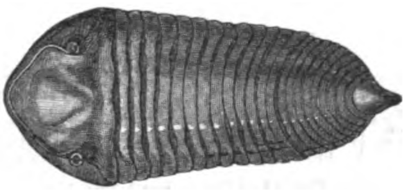


FIG. 256.—Homalonotus delphinocephalus. König.

LOWER DIVISION OF THE UPPER SILURIAN SYSTEM.—The lower division, comprising the Wenlock formation, is again subdivided into two portions, the upper being the Wenlock, formerly called the Dudley limestone, and the lower the Wenlock shale. Its characteristic fossils may be regarded as the two forms of trilobite, *asaphus** *caudatus* and *calymene Blumenbachii*, together with corals of the genera *catenipora*, *porites*, and *cystiphyllum;* the organic remains of this deposit partaking rather of the lower Silurian formations beneath, than of the upper Ludlow which lies above them.

II.—THE LOWER SILURIAN ROCKS.—These have again been sub-divided into two portions, the Caradoc sandstone and the Llandeilo flags, the former occurring in the vicinity of the Caradoc hills in Shropshire, the latter in Wales, being named from a town in Caermarthen-

* Concealed, because no traces of legs have been discovered, from *a* privative and σαφης, *manifestus*.

shire, where they are developed, and being composed of dark micaceous grit or sandstone.

THE CARADOC SANDSTONE.— The characteristic fossils of this deposit consist of various species of *atrypa*, *leptæna*, and *orthis*, together with the still problematical fossil termed by Schlotheim *tentaculites scalaris*.

THE LLANDEILO FLAGS.—These contain, as their characteristic shells, several species of *euomphalus*, *lituites*, &c., together with the two large forms of *asaphus* named by Brongniart *asaphus Buchii*, and *asaphus tyrannus*.

EXTENSIVE GEOLOGICAL DISTRIBUTION OF THE SILURIAN DEPOSITS.—The Silurian strata have been discovered in various and extensive parts of the continent. While Mr. Murchison has explored and detected them in the central and remote parts of Europe, in Belgium, the banks of the Rhine, Westphalia, and Nassau, as well as in the north of Germany, in the extreme parts of Russia, and at the very confines of the old world; Mr. Lyell has discovered them in the new, and recognized them at various points of the American continent.

While the above compendious description will afford a general idea of this formation with reference to its geographical distribution, lithological characters, and imbedded fossils, we must refer for a complete and satisfactory account of strata, thus interesting and extensive, to the writings of that English geologist who has investigated them with so much advantage to science, so much benefit to the community, and so much fame to himself; and who has so honourably associated the name of Murchison with that of the Silurian system of deposits.

The accompanying illustration depicts the most prevalent forms of shells.

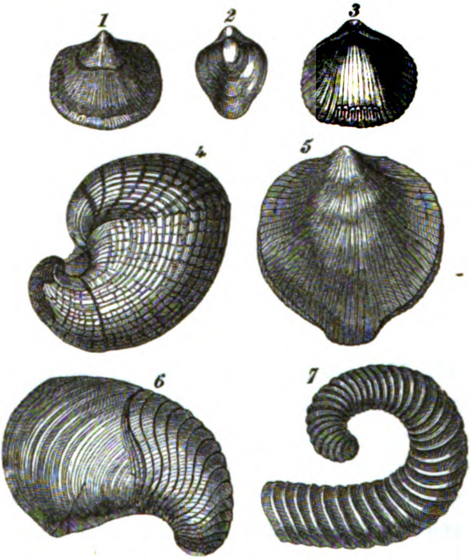


FIG. 257.—1. Orthis orbicularis. 2. Terebratula navicula. 3. Orthis navicularis. 4. Pentamerus Knightii. 5. Atrypa affinis. 6. Orthoceras ventricosum. 7. Lituites giganteus.

EXERCISES

ON THE SILURIAN SYSTEM.

State, as before mentioned, the various collections of the system, the different localities of its beds, its general characteristics, its geographical distribution, and principal organic remains; and practise the usual mode of question and reply.

CHAPTER XXI.

CAMBRIAN AND CUMBRIAN SYSTEMS.

AUTHOR:—PROFESSOR SEDGWICK.

MUSEUM.—GEOLOGICAL SOCIETY.

THE METAMORPHIC AND PLUTONIC SYSTEMS.

CAMBRIAN SYSTEM OF PROFESSOR SEDGWICK.—This formation consists of a vast series of rocks, of slaty character, in some of which fossils have been found, though no extensive assemblage of organic remains, specifically distinct, has hitherto been determined. Some of the upper beds contain corals and shells, and Professor Phillips has discovered two species of corals (*cyathophyllum*) and six of the older forms of *terebratula*, in the strata of Snowdon. The system extends over a great part of Cumberland and Westmoreland, and is largely developed in North Wales, whence its name.

The following is the tabular arrangement of these deposits, adapted by Professor Sedgwick.

CAMBRIAN SYSTEM.

Plynlymmon rocks.—Argillaceous indurated rocks, sandy or slaty.

Bala limestone.—Dark laminated limestone and slate.

Snowdon rocks.—Fine and coarse-grained slaty rocks.

The Cumbrian system is a term applied to vast accumulations of rocks, occurring chiefly in the neighbourhood of the lakes of Cumberland, and for the most part of slaty texture, and devoid of fossils.

METAMORPHIC ROCKS: MICA-SCHIST AND GNEISS SYSTEMS.—Our previous observations (see page 212) have so far tended to explain the character and origin of these deposits, that a lengthened detail in this place would tend rather to embarrass than assist the student, and a brief recapitulation of their most important characters will suffice for the present purpose.

The best general idea which the student can perhaps form of these formations is, as previously stated, to regard them as possessing an intermediate position and character between the sedimentary rocks above and the plutonic deposits below, with both of which they are intimately connected. On the one hand, they resemble the sedimentary rocks in the circumstance, that they exhibit marks of stratification; while they are still more intimately associated from the fact, that many of the upper, slaty beds of the system pass into overlying, slaty deposits, which are unquestionably of aqueous origin. On the other, they are allied to the formations beneath, by the circumstance of containing no organic remains; while they are still more closely blended from the fact, that they often graduate into the granite of the underlying plutonic system. The splendid conception of Dr. Hutton, described in a previous page, by which the whole of the primary rocks, stratified and unstratified, are considered to be merely sedimentary deposits, variously acted on by heat, affords the only means of reconciling, in a satisfactory manner, the common origin

of these rocks, with the varied and dissimilar aspects which they now present.

THE MICA-SCHIST SYSTEM.—Mica-schist is essentially composed of mica and quartz, the two minerals being disposed in alternate layers, forming laminated strata, which are extremely wavy and contorted. The upper beds approach the character of clay-slate, presenting laminæ of mica, chlorite, talc, and hornblende, together with limited beds of crystalline limestone, iron ore, &c.; the lower are of more quartzose character, consisting of quartz and mica, quartz and chlorite, and quartz rock. Its British localities we have already mentioned as being the Highlands of Scotland and the north-west of Ireland.

THE GNEISS SYSTEM.—Rocks of this character form the lower portion of the series. The gneiss itself is composed of the same elements as granite, mica, quartz, and felspar, and these being arranged in layers, which are undulated, or contorted, it may be considered slaty granite. The system, as before stated, also contains, in addition to beds of gneiss, deposits of mica-schist, quartz-rock, primary limestone, hornblende-schist, and clay-slate, alternating in a very irregular manner. We have already adverted, in an early portion of this volume, (page 70,) to an opinion expressed by Professor Phillips, in his Treatise on Geology, in the Cabinet Cyclopædia, which is in effect as follows. Whereas the gneiss, and the mica-schist, are regarded as metamorphic rocks; in other words, as sedimentary deposits, metamorphosed and rendered crystalline by heat; the professor conceives, that the metamorphism, in the instance of gneiss, appears to have been but partial, and

that this rock has resulted from the abrasion and disintegration of granite, and has been deposited in its present form and texture by an ocean, the waters of which were, probably, too warm for the support of animal life. On the other hand, it may be urged that the graduation of gneiss into mica-schist, and various slaty rocks, and of these last into rocks which are unquestionably of aqueous origin, confirm the probability of the whole being of the common origin to which Dr. Hutton has assigned them, and owing their present dissimilarity of texture and aspect to the dissimilar degrees of heat to which they have been exposed.

The stratification of gneiss is more or less distinct; the strata are often inclined to the horizon at a very great angle; and indeed they are sometimes nearly, if not quite, vertical. Mountains composed of gneiss are seldom so steep as those of granite; and their summits, instead of presenting needle-like points or pinnacles, are usually rounded. Gneiss is one of the most metalliferous of the primary rocks, its ores occurring both as beds and veins, but more frequently in the latter form. The localities in which gneiss occurs in this island are the north and north-western parts, and the Western Isles of Scotland.

THE PLUTONIC, OR MELTED ROCKS.—These, as we have already mentioned, page 203, are usually divided into two classes, the trap-rocks, comprising the basalts, porphyries, and their associate substances, and the granite, and their kindred rocks. The trap-rocks, as before mentioned, commonly occur in the shape of veins or dikes, as depicted in the accompanying illustration, which represents a vein of porphyry, traversing argillaceous schist, St. Agnes, Cornwall.

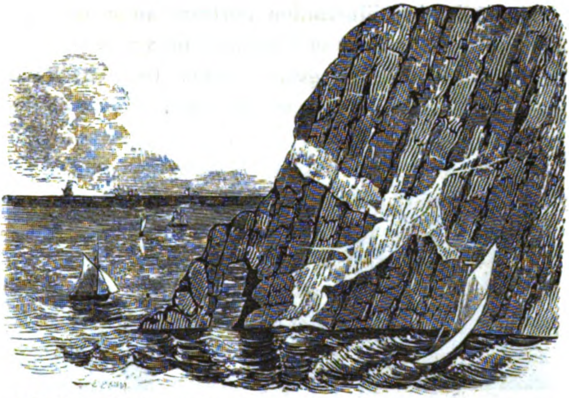


FIG. 258.—Vein of porphyry, traversing argillaceous schist, St. Agnes, Cornwall.

Their columnar arrangement is developed at the cave of Fingal, in the Isle of Mull.

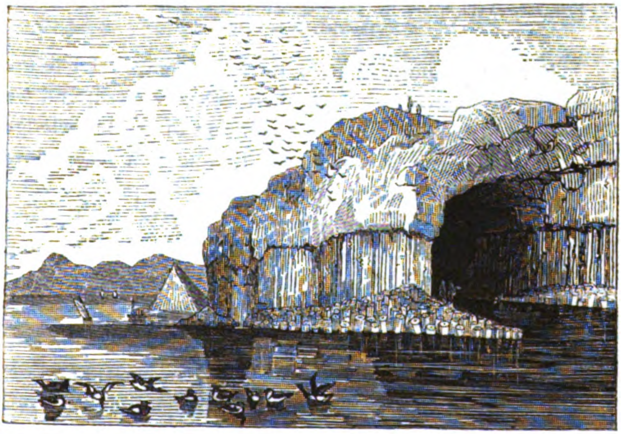


FIG. 259 —Entrance to Fingal's Cave.

The following illustration portrays an instance, occurring in the vicinity of Carlsbad, of a vein of granite traversing a mass of granite older than itself, and proving the different ages of this rock.

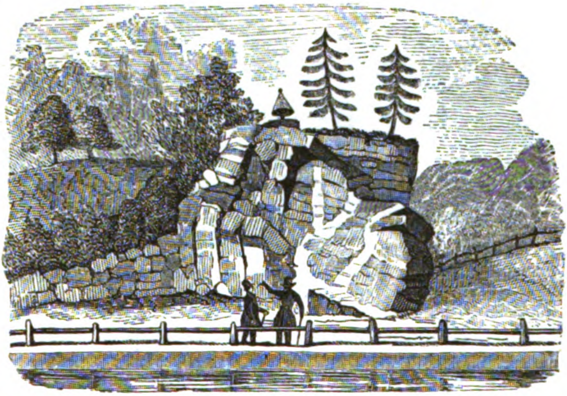


FIG. 260.—Vein of granite, penetrating a mass of granite older than itself, in the vicinity of Carlsbad.

For more minute details, we would again refer to the works of Macculloch and others, already cited, and we may add, that, as the latest addition to our knowledge of these deposits, Mr. Wallace, in a memoir read before the Geological Society, May 24th, of the present year, proposes to divide the granitic rocks into two classes; the first of which comprises granites, in the composition of which the alkaline earths form no essential part; whilst in the members of his second class, they are essential ingredients. His first class is divided into two orders; the first, called by Mr. Wallace *perfect granite*, is a ternary compound of quartz, felspar, and di-axial mica, universally diffused, and generally coarse-grained, when found in mass; the second order he calls *imperfect*

granite, including the compounds of felspar and mica, without quartz, and of quartz and felspar, without mica. He believes there is no binary granitic compound of quartz and mica, as such would be incapable of assuming the granitic structure. In his second class he includes three divisions: 1st, *hornblendic granite;* 2nd, *talcose granite*, or protogine; and 3rd, *schorly granite.* Each of these orders includes several varieties. Of these various granites the author regards the ternary, composed of quartz, felspar, and binaxial mica, as the lowest accessible rock of the earth's original crust, uplifted and protruded through sedimentary strata at different periods, from the earliest to the latest age of igneous disturbance. The fine-grained varieties of ternary granite, which are often found in veins, have probably been fused a second time. The seat of the binary granites was probably below that of the ternary rock, but higher than that of the granites, which contain alkaline earthy substances. In general, the conclusion of the author is, that the absence of mica, or the presence of minerals abounding in magnesia or lime, or that of metallic oxides, or a transition into syenite, porphyry, basalt, or volcanic rocks, are indications of an origin of later date than that of ancient granite.

We have already mentioned the classification of the whole of the primary deposits into a three-fold division, as the most natural and intelligible arrangement, and have attributed their texture and aspect, in a general way, to the agency of heat; the metamorphic rocks being conceived to have been merely altered by its action, while both the trap-rocks and granites have been reduced to a state of fusion, the trap-rocks having been ejected beneath the waters of the ocean, and the granites having crystallized,

from a melted condition under the weight and pressure of the strata. With reference to the granites, it may be observed, that mountains of this rock are usually extremely steep, and that their summits present those notched or serrated edges, which, in the languages of the south of Europe, have occasioned the name of Sierra to be bestowed on hills of this character. We have already mentioned that the granite rocks occur as dikes and veins, which pierce through the incumbent deposits, and occasionally penetrate to the top, spreading and towering over all they have displaced. We have also named that veins of granite are frequently traversed by other veins newer than themselves, and have stated that granite is thus proved to be of all ages, and to have been fluid as late as the close of the secondary, and even during the tertiary period. We have also adverted to the fact, that it has been protruded in a solid as well as a fluid condition, and have instanced the proofs of its solidity, when ejected, as being evinced by the absence of any dikes or veins ramifying into the surrounding rocks, and of any marks of charring or calcining, as well as by evidences of rubbing and abrasion, and by masses of conglomerates and breccias occurring at the line of junction. We have farther alluded to the splendid theory of Dr. Hutton, who conceives that the granite, as well as the whole of the non-fossiliferous deposits, is no independent formation, but merely so much sedimentary substance which has been fused by heat; in short, so many sandstones, limestones, clays, &c., which have first been melted, and then have cooled to their present crystallized condition; that it is, in reality, no separate structure, but merely the pavement of that temple which the Almighty has filled with so many

monuments of his wisdom, benevolence, and power. And, as in alluding to the antiquity of our earth, we cited the existence of kindred spheres, so remote, that millions of years are requisite to transmit the light from those planets to our own, and, as we inferred, that had we power to attain to those distant orbs we should behold by no means the limit of creation, but only its beginning, and should look not on the blank termination of the universe, but only on fresh worlds of light and life beaming throughout illimitable space; so it is conceived that could we penetrate the secrets of these deeply seated and mysterious formations, and learn the history of their origin, we should find that we had reached, not the end of creative power, intelligence, and goodness, but only their beginning, whence we could look forth into spheres of wisdom and perfection unknown, unsuspected before.

Conclusion.—Having thus arrived at the termination of our task, we will detain the reader for a moment only at parting, while we review the objects which we have proposed in this work, and the means we have pursued in attaining them. Conceiving, as already stated, that the numerous excellent treatises already published still left room for another of more introductory character, and that their authors frequently supposed a degree of knowledge, on the part of their readers, which was not always possessed, the writer has endeavoured, in the present attempt, to supply information of the most elementary kind, and to teach at least the rudiments of those studies, the knowledge of

which constitutes the attainment of geological science. The interest and instruction afforded by these pursuits are obvious to all who cultivate them, and the mere mention of their chief attractions will prove a sufficient recommendation.

How fascinating is mineralogy! how instructive that science which, from the icicle to the diamond, and from the drop of water to the starry orbs above us, teaches the laws which regulate form, and which are as prevalent as they are powerful, as simple as they are sublime!

How engaging is the knowledge comprised in the term physical geology; the history of the deposition of sedimentary substances by aqueous, and their disturbance by igneous action; of the mighty contest between the opposing forces of fire and water, those antagonist powers to which the Almighty has so admirably delegated the task of renewing and perpetuating the solid crust of the earth; their seeming strife issuing in order and peace, their apparent conflict harmonizing into beauty, fertility, and perfection.

And, ascending to the animated objects of creation, how attractive is conchology; how admirable the lessons conveyed by this apparently subordinate, yet really important study! How lovely are the shells! how symmetrical—how beautiful! How vivid their colouring; how elegant their form; their convolutions how delicate; their outline how graceful; their adaptation how skilful; their entire structure how perfect!

Passing onwards to fossil botany, how impressive is a study which, from a mutilated stem, or a fragmentary leaf, or from the mere impression which these evanescent substances have stamped and "graven on the rock for

ever," enables us to restore the vegetation and temperature of the primeval earth at a period when our English vales were rich savannahs, thick and matted jungles, or rank and swampy marshes, abounding in gigantic mosses, colossal reeds, or huge aquatic plants; its forests groves of tree-ferns, palms, bananas, and bamboos; its climate hotter than the torrid zone!

And again, reverting to the animal population of those by-gone eras, how engaging is palæontology!—how instructive a study which teaches the changes in animal life, consequent on mutations of climate; the extinction and substitution of races observable on our earth, abounding, as it has done, first in corals, shells, and fish of forms wholly unknown at the present day; next in reptiles of dragon-like appearance, and colossal size; these, after a lengthened period, succeeded by mammalia of tropical form and nature, the elephant and the mastodon, the megathere and the deinothere, until the climate gradually moderated, and with it the types of existence, till nature by degrees presented, both in her temperature and in her animal and vegetable forms, the aspect which she wears at the present day.

It were superfluous at this moment to dwell at any length on the praise of such pursuits—they are their own recommendation, and their own reward. It may, however, be permitted to congratulate both the scientific and the general public, that the prejudice and odium once so unjustly and so absurdly attached to such inquiries, and to those who cultivate them, have now disappeared, and that the period is happily past when geology was confounded with infidelity; and when, to look into the works of the Creator, was regarded as an act of impiety against Himself. An utter revolution of

sentiment has now taken place; and theirs is felt to be the impiety, theirs the crime, who would dare to identify ignorance with devotion, and forbid us to exercise the god-like faculty with which the Almighty has endowed even the least-gifted among us, that of adoring the Creator in the creation, and tracing his perfections in his works. It is, in truth, in inquiries of this nature, that we employ the noblest powers, and realize the highest ends of our being. Mind acts on matter, and matter re-acts on mind, till not only is the material world around us advanced in interest and instruction; but we ourselves are impelled onward in the great career of intellectual advancement and moral improvement, and rendered wiser and better beings. And looking forward past all mere present advantages, if, as who can doubt, the happiness of a future state shall consist in the perfection of the highest faculties of this, we shall, by such contemplations, anticipate in this life the felicity of a better, and realize the bliss of an existence, in which we are expressly informed by the most philosophic of the Christian inspired writers, that, "we shall know even also as we are known!"

APPENDIX. (A.)

DIRECTIONS

FOR

COLLECTING SPECIMENS OF GEOLOGY AND MINERALOGY,

FOR THE BRITISH MUSEUM.

BY C. KONIG, ESQ., KEEPER OF THE MINERALS.

The following short directions being intended for the use of such persons as are supposed to be entirely unpractised in geology and mineralogy, all technical terms, the understanding of which pre-supposes an acquaintance with those sciences, have been carefully avoided; as likewise, all references to the relative order or superposition of rocks, and the succession in which many of the materials to be collected are known to be disposed with respect to each other.

1. Common boulders, rolled pieces of rocks, or their fragments, pebbles, &c., picked up at random, in situations of no peculiar interest, are very seldom of any scientific utility; they had much better be left where they are, than made the source of embarrassment to those who are expected to arrange and incorporate them

with objects of systematic geological or mineralogical collections. But boulders, rolled pieces, rubble-stones, and even gravel, sand, silt, and other loose materials, may prove objects of real scientific importance to the intelligent, although unscientific observer, in proportion as the nature and mode of their occurrence are ascertained, or appear to him to be connected with interesting circumstances and questions; such as their probable origin, and whether they may be considered as gradually washed down from higher levels by rains, rivers, &c.; or as remnants of broken-up beds of lakes or seas, (for both kinds have often been indiscriminately called alluvial,) &c. He will often find them to contain well-preserved remains, such as teeth and bones of the elephant, hippopotamus, rhinoceros, petrified wood, &c. Also, interesting mineral substances, such as particles of metallic ores, gems, &c., are frequently found imbedded in those deposits of loose materials; let him carefully collect, label, and preserve such objects. With regard to loose blocks, specimens should in general be detached from such only, as, from the situation in which they are found, and from other circumstances, have evidently not formed part of neighbouring masses, and which are, therefore, called erratic blocks. Masses of cliffs and rocks precipitated from above, at recent periods, may, however, often supply the collector with good specimens of strata not easily accessible to him.

Materials for roads, thrown out in heaps, may furnish specimens for collections; but the places from whence they are obtained should be previously ascertained. Road-stones are frequently brought from very distant quarries.

2. Upon the whole, rock-specimens should be taken fresh from the masses in their native places. Among localities most favourable for this purpose, the following may be specified:—cliffs on the sea-shore—they frequently afford very perfect sections of the masses and strata of rocks; precipitous sides of rivers, and their beds, and of mountain-streams, which often lay open strata and beds at depths otherwise difficult to discover; ravines and deep valleys transversely crossing the strata, and the naked sides of which, especially when long operated upon by rivers and mountain torrents, often present instructive profiles of stratification; artificial sections of ground, such as are produced by quarries, gravel-pits, and excavations, of every description, for roads, canals, tunnels, wells, &c.

3. Where mines are worked, the collector will generally find some well-informed person or other to assist him in his pursuits; but he should use circumspection in making purchases of specimens from the common miners.

4. Not unfrequently, one and the same mass of rock exhibits great diversity of aspect, through the variation which takes place in the mixture and proportion of its component ingredients, their colour, &c. Also the texture, such as the crystalline-granular, the slaty, the compact, &c., are subject to variation, and gradual changes have often taken place through atmospheric influence, sometimes to a considerable depth into the mass. Accidental admixtures, not essential to the rock, are likewise frequently observable. As in such cases a few specimens would convey but an imperfect idea of the true character of the stratum, or other mass

of rocks, suites of specimens should be formed, illustrative of most of the varieties which it affords.

5. The thickness of each stratum or bed, and other circumstances connected with them, such as their horizontality or inclination, and the angle under which, and toward what part of the compass they incline, should be regularly noted. Slight sketches of the stratification of a coast or cliff, marked with numbers corresponding to those on the labels of the specimens obtained from those strata, will be found greatly to abbreviate the trouble of writing descriptions on the spot.

6. Examine all places where coal-pits are sunk through different strata; procure specimens from these, and likewise of the different varieties of coal, paying particular attention to specimens of vegetable impressions which they, or any of the accompanying rocks, such as sandstone, &c., may afford.

7. No opportunity should be neglected to procure secondary fossils of every description, accompanied by specimens of the masses in which they are imbedded, and which are not seldom chiefly characterized by them. Interest should, therefore, everywhere be made with quarry-men, and persons engaged in all sorts of works of excavation, to preserve whatever may be found by them in the way of petrifactions, especially osseous remains; and those persons should be particularly cautioned against breaking to pieces whole skeletons, or large portions of them. If possible, the collector should in person superintend the excavation. The following suggestions, taken from Sir H. De la Beche's excellent treatise, "How to observe in Geology," particularly apply to osseous remains of an extremely delicate

structure. Instead of endeavouring to extract these on the spot, the observer should detach so much of the rock as shall, to the best of his judgment, envelope the organic remain in a protecting case suitable for the purpose of transport. Organic remains are generally in better condition, according to the little that is done to them prior to their final deposit in the Museum. If a fossil proves brittle to such a degree that the vibrations produced by blows to its matrix cause it to splinter up, the splinters, if sufficiently large, may be re-adjusted; but it is most advisable, on seeing a fossil begin to splinter, to take some stiff clay, if such can be procured, and press it down upon it. Wax, or similar materials, might advantageously be employed for this purpose, with small specimens. With regard to objects of great rarity and importance, and which rest exposed in a very friable rock, it may even be desirable to prepare plaster of Paris on the spot, and cover the fossil (such as the skeleton of a saurian, &c.,) with a thick coating of it. By this process the exposed part of a skeleton is set, as it were, in a block of plaster, from which, after carefully working beneath it and the fossil in a friable rock, it may afterwards be freed, or in which it may be allowed to remain, as may be desired. When the scattered, yet well-preserved fossil bones of animals are found, it often happens that a large portion of the entire skeleton may be eventually obtained by diligent search. The accidental discovery of a small portion of bone rising through the rock may lead to that of entire skeletons, if sufficient care be employed.

In many slaty rocks fishes, plants, and other organic remains abundantly occur among the laminæ, pressed

down to so thin a substance as not readily to be seen in a cross fracture of the rock. When, therefore, such organic remains are suspected to exist in a schistose rock, detached portions of it should be struck so as to lay open the stones in the direction of the laminæ. In this way multitudes of fossil plants may be obtained, of which there were few traces in the cross-fracture of the rock.

8. Wherever deposits of secondary fossils are observed, it is of importance to note any striking circumstances relative to their mode of occurring; the proportion, for instance, in which the several species are distributed; whether they are more abundant in one bed of the rock than in another; whether they are dispersed in a confused manner through the mass, or arranged parallel to the general stratification, or confined to the surface of any particular stratum; or, with regard to their individual position, whether shells, for instance, are found all exhibiting the same view; or if fishes affect a general uniform position or parallelism of their sides to the stratification; and such other peculiarities as cannot generally be exemplified even by whole suites of specimens.

9. Uncommonly interesting are the osseous remains of caverns and grottos which frequently occur in limestone rocks; these should be diligently sought after and visited, even where report may represent them as not being ossiferous. The collector, in his examination, should proceed systematically by cutting through the layers of the incrustations which he may find at the bottom of them, and which are formed by the dripping down of water impregnated with calcareous particles;

let him form a series of specimens from the layers of this stalagmitic deposit; as likewise of the alluvial matter beneath it, of the gravel, sand, and mud, which usually envelop the osseous remains. Of these latter he should form a complete series, not only as regards the natural difference he may observe in the several bones, but likewise the accidental changes observable in them, such as appearances of being gnawed, fractured, &c. Also other objects which may be found near to, or accompanying the bones, such as rounded concretions, fragments of stones different from the rock of the cave should be collected, and their manner of occurring noted on the labels. In the same manner the collector should not neglect recording every circumstance which the specimens alone are not calculated to illustrate, such as the distribution of the various bones in the caverns, their relative abundance, &c. He should also make memoranda relative to the nature and situation of the cavern itself, its direction, its dimensions, the presence or absence of water in it;—or whether it be furnished with fissures, particularly vertical ones; and if so, whether these be partly open, or filled with bones and rubble cemented together; whether parts of the sides near the opening exhibit a polish as if produced by rubbing against; together with other appearances which are likely to strike an attentive observer.

If fissures in limestone rocks should, on examination, prove to be filled with osseous remains, cemented together by calcareous and other matter, it will be desirable, for the purpose of ascertaining whether bones of different animals are found at different depths, to extract them from the lower as well as the higher portions of the

fissure, and carefully to note the succession of the several specimens thus obtained.

10. Where petrifying sources, as they are called, occur, or waters impregnated with calcareous and other matter, thrown down and consolidated into masses enveloping branches and other parts of vegetables, &c., the collector should, together with specimens, obtain any information within his reach, relative to the condition under which such deposits have been, or continue to be formed. In general it is also desirable chemically to examine such, and other waters remarkable for any striking peculiarity. They may readily be transmitted in clean, strong bottles tightly closed, sealed, and labelled.

11. In tracts of country where volcanos are in action, especially if still unexplored by geologists, not specimens only should be collected, but likewise all the historical data that can be obtained relative to the different eruptions and other phænomena connected with them; and all such circumstances should be noted as in any manner relate to the nature and appearance of those volcanos—their situation, form, craters, &c.; together with every particular concerning the lava-currents, their heat before consolidation, their direction, &c., and perfect suites should be formed of the various volcanic ejections. In endeavouring to detach specimens from a current of lava, the collector should not confine himself to the upper crust of scoriæ; but should likewise obtain fragments from the middle and lower beds. Ashes and other pulverulent volcanic matter are best preserved in strong bottles. Where they are found to enclose organic or other objects, these should be particularly attended to.

12. With regard to certain other rocks, to which the term trappean is applied, and which are now likewise generally considered as igneous, or as having been propelled, when in a state of fusion, through various rocks which they overlie, the collector, under the supposition that he is not altogether unacquainted with some of these rocks, such as basalt and porphyry, is desired to direct his attention to any alteration that may be observable in the condition of the strata in immediate contact with them. These conditions relate to change of colour, lustre, texture, partial fusion or vitrification, &c., and many of them may be illustrated by suites of specimens carefully and judiciously selected.

13. An enumeration of the several instruments required by the geological traveller, for determining the direction and inclination of the strata, for measuring heights, &c., as likewise those for mineralogical investigation, would be superfluous to the proficient in geology and mineralogy, and of no avail to the less scientific collector, who, if he wish for information, is necessarily referred to treatises on those sciences. It is, however, otherwise as regards that indispensable implement, the hammer. Two of these, at least, are required; one weighing from two to four pounds and a half, for breaking the masses; the other of smaller dimensions, for trimming and fashioning the specimens. Common hammers are not fit for the purpose; they should be of well tempered steel, the handles of very tough wood, and most firmly inserted in the heads. The diagrams here given represent those more commonly used, and which may be had of Messrs. R. and G. Knight, Foster-lane, London. Figs. 1 and 2 are of the forms recommended by the late Dr. M'Culloch; fig. 3, is known

by the name of Sedgwick's, and fig. 4 by that of De la Beche's *geological* hammer. The remaining figures (ex-

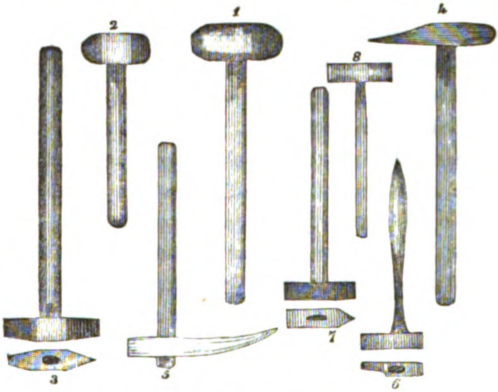


FIG. 251.—Models of Hammers.

cept No. 5) are those of *mineralogical* hammers of various forms and dimensions.

A few mason's tools or chisels, and a small miner's pick, fig. 5, may likewise be occasionally found useful. A glove of thick leather for the left hand, on which the specimens are trimmed; and for their conveyance, a bag (likewise of leather), thin and cartridge paper for packing, small pieces of paper ready cut for labels, and paste or thick gum-water to affix the numbers to the specimens, constitute, together with wool and cotton for delicate secondary fossils, minerals, &c., all the apparatus that is needful to those who undertake the task of collecting.

14. No particular rules can be given for the operation of breaking, trimming, and fashioning rock-specimens; but the skilful management of the hammer, though some

patience and practice be required, is by no means of difficult acquisition.

Specimens intended for public collections, generally speaking, should be of rather large dimensions; some masses, especially compound rocks such as conglomerates, &c., cannot, in all their characteristic parts, be studied from diminutive fragments. A convenient size is four, to four and half, by three inches, and three quarters of an inch to one inch in thickness. Regularity of shape considerably facilitates the proper and safe packing of the specimens. Trim and fashion them on the spot, where there is abundance of materials; what you intend to be the finishing blow with your hammer will sometimes spoil a specimen. All the surfaces must exhibit a fresh fracture, except where it is desirable to illustrate disintegration through atmospheric and other influences; in which case more than one specimen should be obtained.

15. Each object should have its number affixed by means of thick gum-water or paste, and be accompanied by a ticket on which the exact locality is given, together with such information relative to the nature of the masses from which it is taken as the specimen alone is not calculated to convey:—whether they occur in distinct concretions, columnar, &c.; or, if stratified, what is the thickness of the stratum, its inclination to the horizon, &c. The numbers on the specimens may, at the same time, correspond with those of the notes of his road-book, if such be kept by the collector.

16. Great care should be bestowed on the proper packing of the objects. Each specimen is to be wrapped up in two papers; the inner soft, and less substantial than the outer. Put at the bottom of the packing-case

a layer of hay, chaff, moss, or other soft substance, perfectly dry. Place on it the specimens edgewise and in close contact with each other, so that nothing can displace them. Fill up the interstices with moss or tow, and place the other specimens in the same manner, layer upon layer, until the box is nearly full, when the remaining vacuities are to be closely filled up with the same moss, &c., before the lid is fastened. The use of saw-dust for this purpose is not to be recommended. Loose fragile shells and other small delicate objects are best packed by putting them, enveloped in cotton, in rows, and rolling these up in sheets of stiff paper.

17. Still greater care is to be bestowed on such mineralogical specimens as present delicate crystallizations. These, after being wrapped up loosely in silk paper, should be put up separately in a chip-box each, and the empty space filled up with cotton. The chip-boxes are to be placed at the bottom of the packing-case. Minerals, not soft or brittle, may be wrapped up and packed nearly in the same manner as geological specimens. They are to be placed upright in rows one above the other, and with their principal surfaces parallel to two opposite sides of the packing-case. The weight of such case for land-carriage, or shipping, should not exceed one hundred weight.

18. As the geological collector cannot be expected to discover, in his excursions, many specimens of simple minerals desirable to be placed in the national collection, he will do well if he fall in with persons acquainted with, and in the habit of procuring such, to secure their services, with a view to obtain all mineral substances that are peculiar to any particular colony or tract of country; or that claim attention on the score of their

superior beauty and perfection of crystallization. This latter character should be particularly attended to; it is, however, to be observed, that minerals not presenting it, may nevertheless prove highly interesting in other respects, and that a remarkable locality alone may often lend importance to a mineral which is abundantly met with at home.

APPENDIX (B).

[The circumstance, that the following attempt to describe a day of most instructive and delightful enjoyment, is now out of print, may possibly plead in excuse of its insertion here.]

A RYGHTE TREWE STORYE

OF A WAULKE AND TAULKE,

ABOWTE

GEOLOGYE AND HYSTORYE.

GOD prosper longe our ladye Queene,
  Our menne of scyence alle!
What pleasynge waulkes—what learnedde taulkes,
  On Sussex Downes befalle.

Mantell, who late toe Lewes* broughte
  His followers, fonde and trewe;
Nowe clymbed the Steynynge hilles, and soughte
  " Fresh fyeldes and pastures newe!"

* Alluding to a former lecture.

And showed again o'er vale and hille,
  With learnedde taulke and toyle,
The deedes of old—and older stille,
  The wonders of the soyle.

First, att the ryver* halted wee,
  Whyle Mantell toke his stande,
And tolde the marvelles of the sea,
  And chaunges of the lande.

" The insecte smalle," quod he; " the whyle
  Itt flytts among the flowers,
Thynkes them eternall: do ye smyle?
  Itts errour is but owres!

" Wee, too, throughowte lyfe's lyttel daye
  Look owre eche tranquill scene,
And fondlie thynke 'twill be for aye,
  And so hath ever bene!

" Butt knowe thatt once noe ryver flowed
  Throughoute these smyling fyeldes;
Butt farre-off waters drayned the landes,
  And rann thro' dystant wealdes!

" And when some vaste expansyve forse
  Broke upp the ocean's bedde,
'Twas then this ryver found its cowrse,
  And thro' these valleys spredde!

" And soe, when wee shall vanyshed bee,
  Lyke change shall then come owre;
The sea bee lande,—the fyelde a strande—
  The ryver flowe noe more.

* The Adur, which flows into the sea at Shoreham.

"Butt lett us nowe from Nature's workes,
Toe deedes of mann resorte,
For knowe that yonder humble toune
Was once a royall porte.*

"Here, Edwardes, Henryes, sallyed forthe,
Wyth banner and wyth launce,
And ofte our monarches sayled from hence
Toe conqueste and toe Fraunce;

"And whenn agaynste th' Armada's force
Our fathers dared to stryve,
Thys porte sent syx-and-twenty shyppes,
Ande London twenty-five!

"Thus, if wee Nature's workes exhume,
Or owre past hystorie range,
We finde both mann and Nature's doome
Is one perpetuall change!

"Butt seeke we now the churche, and viewe
Its auncyente, sacredde pyle;
Where Saxonn wythe the Normann arche
Dothe blende its varyedd style!

"And see, in form of Holye-Crosse
Was buylte the blessed fane,
To keepe in mynde the Savyour's losse,
And mann's eternal gayne!"

* Shoreham.

And nowe o'er vale, and mount, and dale,
His followers Mantell broughte;
And whyle he tolde the varyed tale,
This was the lore hee taughte:

"The dystante wealdes yee gaze uponne,
Once swarmed with monsters rare;
There raunged the vaste iguanodon,
The hylosaurus there!

"And later yett a sea owrspreadde
The spott where nowe we waulke;
And this was once an oceane's bedde,
The oceane of the chaulke!

"And seas more late, in form and date,
Spredde owre the self-same strande;
And many a chaunge most wylde and straunge,
Reversedd the sea and lande.

"And later stille, o'er yonder hylle,
Dydd tropycke creatures roam;
The wyld horse, deere, fownde pasture here;
The elephaunte a home!"

And thus owre valley, and owre mownte,
Dydd Mantell holde his cowrse;
And pausying laste besyde a fownte
He there descrybedd its sowrse.

"This stone of sande, onn which I stande,"
He sayde the streame besyde,
"Beares, deepe and darke, the rypple marke,
Worn by a ryver's tyde.

"And Nature's lawes, from self-same cawse,
  Have marked alyke the clowde;
And e'en the sunn hath grooves uponn
  His dymm and distante shrowde."

And thence toe porche of Steynynge church,
  A fayre and statelye pyle;
And there he tolde its beautyes olde,
  Of nayve, and arche, and aysle.

And next wee seeke the castled peake,
  And gayn itts friendlye towre,
The tyme we fyxe to dyne is syxe,
  And harke! itt strykes the howre!

There vyandes rare are spredde with care,
  And, thankes to frendes, wee fynde
Refreshyng cheere, provyded here,
  For bodye and for mynde!

For harke! they alle, at Mantell's calle,
  Have soughte the castelle keepe,
To heare once more recounted owre
  The chaunge of lande and deepe.

Anonn turn'dd hee to hystorye,
  From earthes, and chaulkes, and marles;
And shewed toe syghte the lyne of flyghte
  Sought by owre second Charles,

When forcedd by fate, and Cromwell's hate,
  He flewe from Worcester fyelde,
And tryedd the chaunce of flyghte to Fraunce,
  Thro' owre own Sussex wealde!

"Looke outt, againe, in yonder lane,
His fyerce pursewers meete,
And rewdelye ryde the Kynge besyde,
And shake hym in hys seate.

"But thankes to love, and Heav'n above,
Hee 'scaped from daunger's snare,
Achieved the flyghte to Fraunce by nyghte,
And landedde safelye there!"

And towlde hee of that lovynge wyfe,*
Who didd herr courage prove,
And peryll'd lybertie and lyfe,
For loyaltye ande love!

For mann, though hee a traytoure bee
Toe trewth and dutye's lawes;
Yett womann deare is styll syncere
Toe love—to honour's cawse!

Agen he towlde the storie owlde,
Yett ever, ever newe,
Of chaunges wyde, in lande and tyde,
That earthe and oceane knewe!

"Butt I will cease and houlde my peace,"
Enthusyaste Mantell saydde,
"Whyle cleare and bryghte, before your syghte,
The charmes of nature spredde.

"For harke! from hylle and vale so stylle,
Ascendes her evening hymne,

* The wife of Colonel Gunter. See the Colonel's narrative in Parry's Coast of Sussex.

That now dothe rayse her Maker's prayse,
And breathes all love toe Hym!

"And marke her fyeldes, her woodes, her wealdes,
Herr panorama vaste;
And see the whyle the sunne doth smyle
Hys lovelyest and hys laste!"

For joyes most sweete are also fleete,—
Now twylyghte's shadowes felle;
Nyghte threwe o'er all her spangledd palle,
And Mantell badde—"Farewell!"

Nowe yee who blame this verse soe lame,
Writt by unlearnedd elfe,
Thynke not hys lore as myne was poore,
But goe next time yourselfe.

You'll synge, I ween, "Long live our Queene;
And Mantell, long live hee!
And when he waulkes, and when he taulkes,
May I be there toe see!"

APPENDIX (C.)

THE NAUTILUS AND THE AMMONITE.

The extinction of an entire genus is strongly exemplified in the instance of the ammonite. The two shells occur in the earliest formations, and both are found simultaneously up to the chalk, where the ammonite ceased to exist, no specimen of that genus being found in deposits which overlie that deposit, while the nautilus survives at the present day. This separation,—the fact that "the one is taken and the other left," has appeared to the author a fit subject for poetic illustration, and has given rise to the following lines.

THE nautilus and the ammonite
Were launched in friendly strife;
Each sent to float, in its tiny boat,
On the wide wild sea of life.

For each could swim on the ocean's brim,
And when wearied its sail could furl;
And sink to sleep in the great sea-deep,
In its palace all of pearl!

And theirs was a bliss more fair than this,
Which we taste in our colder clime;
For they were rife in a tropic life,
A brighter and a better clime!

They swam 'mid isles whose summer smiles
Were dimmed by no alloy;
Whose groves were palm, whose air was balm,
And life—one only joy!

They sailed all day, through creek and bay,
And traversed the ocean deep;
And at night they sank on a coral bank,
In its fairy bowers to sleep!

And the monsters vast, of ages past,
They beheld in their ocean-caves;
They saw them ride in their power and pride,
And sink in their deep sea-graves.

And hand in hand, from strand to strand,
They sailed in mirth and glee;
These fairy shells, with their crystal cells,
Twin sisters of the sea!

And they came, at last, to a sea long past,
But as they reached its shore,
The Almighty's breath spoke out in death,
And the ammonite lived no more!

So the nautilus now, in its shelly prow,
As over the deep it strays;
Still seems to seek, in bay and creek,
Its companion of other days.

And alike do we, on life's stormy sea,
As we roam from shore to shore;
Thus, tempest-tost, seek the lov'd, the lost,
But find them on earth no more!

Yet the hope how sweet, again to meet,
As we look to a distant strand,
Where heart meets heart, and no more they part
Who meet in that better land.

CORAL FORMATIONS.—The following summary of the observations of recent voyagers, on the growth and formation of coral islands, is from the work of Dr. Mantell.

The coral banks are everywhere seen in different stages of progress, some are become islands, but not yet habitable; others are above high-water mark, but destitute of vegetation; while many are overflowed with every returning tide. When the polypi which form the corals at the bottom of the ocean cease to live, their skeletons still adhere to each other, and the interstices being gradually filled up with sand and broken pieces of corals and shells, washed in by the sea, a mass of rock is at length formed. Future races of these animalcules spread out upon the rising bank, and in their turn die, and increase and elevate this wonderful monument of their existence.

The reefs which raise themselves above the level of the sea, are usually of a circular or oval form, and surrounded by a deep and often unfathomable ocean. In the centre of each there is generally a shallow lagoon, with still water, where the smaller and more delicate kinds of zoophytes find a tranquil abode; while the stronger species live on the outer margin of the isle, where the surf dashes over them. When the reef is dry, at low water, the coral animals cease to increase. A continuous mass of solid stone is then seen, which is composed of shells and echini, with fragments of corals, united by calcareous sand, produced by the pulverization of the shells of friable polyparia. Fragments of coral limestone are thrown up by the waves; these are cracked by the heat of the sun, washed to pieces by

the surge, and drifted on the reef. After this the calcareous mass is undisturbed, and offers to the seeds of the cocoa and pandanus, floated thither by the waves, a soil on which they rapidly grow, and overshadow the white, dazzling surface. Trunks of trees, brought by currents from other countries, find here, at length, a resting-place. With these come some small animals, as lizards and insects. Even before the trees form groves or forests, sea-birds nestle there; strayed land-birds find refuge in the bushes; and at a still later period man takes possession of the newly-erected country.

The following lines are intended to convey an idea of some of the most important and interesting phenomena above described, as connected with this singular class of beings.

THE CORALS.

Beneath the realm which the waves o'erwhelm,
In the seas of the torrid zone,
Our ancient race have a dwelling-place,
In a world that is all our own!

Earth boasts no spots like the fairy grots
Where we build our sparry cell;
Nor can its bowers produce such flowers
As in depths of ocean dwell.

And our forms, so strange, we ever change,
As over the deep we roam;
And our varied hue is ever new,
As we vary our ocean-home.

In tranquil calms we wave like palms,
Or bend like the drooping willow;
Or we climb to the verge of the foaming surge,
And dash to the winds its billow!

In peaceful haunts, like tender plants,
We twine our fragile forms;
Or we build a rock to the tempest's shock,
That mocks its fiercest storms!

And we rear the walls of those marble halls,
As a precipice high and steep,
Till a new-found isle is seen to smile,
Like a beacon o'er the deep!

By viewless hands, those new-born lands
Are strewn with blessings rife;
Till man appears, and claims the spheres,
To being raised, and life.

And we join the piles of those fossil isles,
Till they spread from shore to shore;
And we build from the caves of the ocean-waves
A world unknown before!

Then say, proud man, how poor the plan
Of thy pyramids, castles, towers;
How vain the boasts of thy mightiest hosts,
Or their labours—compared with ours!

Though such our lot, yet we are—what?
In the scale of being vast,—
The meanest germs;—of life's poor worms,—
The lowest and the last!

Yet though obscure, and low and poor,
 And lost in distance dim;
We still can raise our Maker's praise,
 And pour our thanks to Him!

COAL.—While the pages of the first edition were passing through the press, the present ministry so far attended to the suggestion of Dr. Buckland, as to impose a duty on the exportation of coal. It is, however, proper to state, that considerable difference of opinion has ever existed on the subject; and that Mr. Buddle, in particular, an observer of great practical as well as theoretical knowledge, has constantly declared himself in favour of unlimited exportation, chiefly on the ground, that by supplying other nations we carry on a profitable trade, and deter them from discovering coal of their own.

It may be added, that models of the smaller portions of the structure of the *iguanodon*, as the teeth, claws, horn, &c., which every collection should possess, may be procured of Mr. Tennant, 149, Strand. Mr. Renfree, of Truro, may be added to the list of dealers in minerals.

GLOSSARY

OF SCIENTIFIC AND OTHER TERMS USED IN THE WORK.

For more ample details, the reader is referred to the excellent work of Dr. Humble.

A.

ACEPHALA.—Mollusca wanting the head, as the scallop, &c.

ALGÆ.—A division of cryptogamous plants, including the sea-weeds.

ALLUVIUM.—Materials transported and deposited by the action of water.

ALVEOLUS.—Socket of the teeth.

AMORPHOUS.—Shapeless, destitute of regular form.

AMYGDALOID.—That cellular structure of the trap-rocks, in which mineral substances are embedded.

ANALOGUE.—A similar representative animal or vegetable, as a recent shell, animal, or plant of a fossil.

ANASTOMOSING.—Running into each other.

ANGLE.—The following observations may be advantageously borne in mind. A right angle is formed by the insertion of two lines which are perpendicular to each other, and which form an angle of 90 degrees, or the fourth part of a circle; the frames which contain a pane of glass are an example; an acute angle is one which is less than 90 degrees;

an obtuse angle, one which is more; an oblique angle is one which is not 90 degrees, and may be either more or less, either obtuse or acute.

ANTENNÆ.—The projecting feelers of insects.

ANTHRACITE.—Stone-coal.

ANTHRACOTHERIUM.—A pachydermatous animal, first found in a bed of anthracite.

ARENACEOUS.—Composed of sand.

ARGILLACEOUS.—Composed of clay.

ANTICLINAL AXIS.—Where the strata diverge from each other in opposite directions. (See p. 243.)

AUGITE.—A mineral resembling hornblende, of dark green or black colour, occurring in volcanic rocks.

B.

BARYTES.—A mineral substance, also called heavy spar.

BASALT.—A mineral composed of augite and feldspar.

BASIN.—A depression of strata, in which accumulations of more modern date are deposited.

BATRACHIAN.—Allied to the frog, toad, &c.

BELEMNITE.—A long, dart-shaped fossil (whence its name,) the dorsal bone of an extinct kind of *sepia*, or cuttle-fish.

BITUMEN.—Mineral pitch, an essential element of good coal.

BLOCKS, ERRATIC.—A term equivalent to boulders, applied to transported masses of primary rocks.

BRACHIOPODA.—Arm-footed; molluscous animals, whose organs of locomotion consist of arm-like processes.

BRECCIA.—A term adopted from the Italian to designate a mass composed of angular unworn fragments of rocks, as conglomerate is formed of worn and rounded materials.

C.

Calcaire grossier.—A series of marine tertiary limestones, occurring in the vicinity of Paris.

Calcareous.—Applied to rocks and other substances, of which lime is the base.

Calcedony.—A form of silex, so named from the city of Calcedon, in Asia, where it abounds.

Carbon.—The elementary constituent of charcoal and the diamond.

Carbonate of Lime.—The combination of lime and carbonic acid.—All limestones and marbles are so composed.

Carboniferous.—Producing coal; a term improperly applied to the deposit also called mountain-limestone.

Cephalopoda.—Mollusca, whose organs of locomotion are arranged round the head.

Cetacea.—An order of mammalia, inhabiting the sea.

Chert.—An impure variety of flint, frequently composed of silex and green sand.

Cilia.—Hair-like vibratory organs.

Concretion.—A combination of separate particles.

Conformable.—Applied to strata lying parallel to each other.

Conglomerate.—A mass composed of rounded waterworn fragments, cemented together; as breccia is used to describe a similar aggregation of uneven and angular materials.

Coniferæ.—Trees bearing cones, containing the seeds, as the fir, pine, &c.

Cotyledons.—Seed-lobes of plants. (See p. 293.)

CRAG.—A provincial term, used to designate the tertiary deposits of Norfolk and Suffolk.

CRATER.—The vent at the summit of a volcano.

CRENULATED.—Notched or toothed.

CRETACEOUS.—Belonging to chalk.

CRINOIDEA.—Lily-shaped animals.

CRUSTACEA.—Animals having an external crust or skeleton, as the crab, lobster, &c.

CRYPTOGAMIÆ.—A class of plants, in which the organs of fructification or reproduction are concealed.

CRYSTALLIZED.—Is used to denote that perfect form of crystallization, of which crystalline implies a less perfect degree. Both are frequently used indiscriminately.

CYCADEÆ.—A peculiar order of plants, natives of the Cape of Good Hope, and intermediate between the monocotyledonous and dicotyledonous classes.

D.

DELTA.—Alluvial deposits, formed by rivers. (See p. 227.)

DENUDATION.—The carrying away a portion of overlying materials by the action of water. (See p. 246.)

DETRITUS.—Disintegrated materials of rocks.

DICOTYLEDONOUS.—A grand division of the vegetable kingdom, applied to plants having two cotyledons, or seed-lobes. (See p. 292.)

DIDELPHYS.—A marsupial animal, allied to the opossum.

DIKES.—The intrusion of volcanic among stratified rocks. The name is derived from the term applied

in Scotland and the north of England to walls, owing to these ejections frequently presenting the appearance of walls, owing to the strata on both sides having been worn away.

DILUVIUM.—A term employed at an early period of the science to designate ancient alluvial deposits.

DIP.—The inclination of strata. (See p. 241.)

E.

ECHINODERMATA.—Hedgehog-skinned; applied to creatures having a prickly external integument, as the echinus, or sea-urchin.

EOCENE.—Dawn of the recent or existing period. (See p. 410.)

ESCARPMENT.—The steep side of a hill. (See p. 249.)

ESTUARY.—Mouths of rivers alternately occupied by the waters of the river and the sea.

EXUVIÆ.—Organic remains.

F.

FAULTS.—An interruption of the continuity of strata. (See p. 254.)

FAUNA.—A term borrowed from the *fauni*, or rural deities of classic mythology, and now used to denote the animals; as the *flora* indicates the plants of any given district.

FELDSPAR.—A simple mineral entering into the composition of granite and several other igneous rocks.

FERRUGINOUS.—Impregnated with iron.

FLORA.—A term employed to denote the plants of any particular region, as the term *fauna* indicates its animals.

FORMATION.—A group or series of strata referred to a common date or origin.

FOSSILS.—The mineralized remains of animals and plants.

FRIT.—A frothy, spongy substance, arising from the imperfect calcination of certain minerals.

G.

GALT or GAULT.—A provincial term for beds of blue clay, which, though strictly applicable only to those of the chalk formation, is locally applied to those of other deposits. Thus the clay beds of the oolite of Huntingdonshire are termed galt.

GELATINOUS.—Jelly-like; semi-fluid like jelly.

GLACIER.—The accumulations of ice and snow in the alpine and other mountains.

GNEISS.—A primary stratified rock. (See p. 213.)

GREENSTONE.—A variety of trap-rock, composed of hornblende and feldspar.

GREYWACKE.—A term applied to rocks of conglomeritic character, bearing marks of induration by heat.

GRIT.—Coarse-grained sandstone.

GYPSUM.—A mineral composed of lime and sulphuric acid; sulphate of lime.

H.

HAMITE.—Hook-shaped. A shell of an extinct genus of cephalopoda.

HOMALONOTUS.—A genus of trilobites, occurring in the Silurian deposits; so named by Mr. Kōnig, from the smoothness of the back.

Hornblende.—A simple mineral of a dark green or black colour.

Hylosaurus.—The lizard of the weald. An extinct lizard discovered by Dr. Mantell in the sandstone of that formation.

Hypogene.—A term used by Mr. Lyell to denote the primary rocks, and signifying that they are formed beneath the surface.

I.

Iceberg.—A term which, derived from the German, literally means a mountain of ice, and is applied to the masses of that substance, often of the size of hills, which float, partly in, partly out of water, both in polar, northern, and southern seas.

Ichthyosaurus.—Fish-like lizard; a gigantic marine reptile, partaking of the characters of the crocodile and the fish.

Iguana.—An existing lizard, a native of India, America, &c., &c.

Iguanodon.—A colossal, extinct saurian, discovered by Dr. Mantell in the wealden formation; so named from its teeth resembling those of the recent iguana.

Imbricated.—Placed one above the other, like the tiles of a house.

Incandescent.—A term applied to mineral masses in a state of fusion.

Induction.—The establishing a general conclusion from various individual facts.

Infusoria.—Microscopic animalcules generated in infusions.

Insectivorous.—Animals that live on insects, as the hedgehog.

Invertebrata.—Animals destitute of a long flexible spine, or vertebral column, as the crab, worm, &c.

Jura Limestone.— *Calcaire Jurassique.* Strata of the oolitic series, which constituting the mass of Mount Jura, derive the name by which they are best known on the continent, from this circumstance.

K.

Kimmeridge Clay.—A thick bed of bituminous clay; so called from the place in the Isle of Purbeck, where it chiefly occurs.

L.

Lacustrine.—Belonging to a lake.

Lamellæ.—Thin plates, like sheets of paper.

Laminæ.—Thin plates.

Laminated.—Arranged in thin plates.

Lava.—The stone flowing in a melted state from a volcano.

Lias.—Corrupted from layers. Employed to designate the formation intermediate between the oolite and new red sandstone.

Lignite.—Wood partially converted into coal.

Lithological.—Used to denote the stony character of a mineral mass.

Littoral.—Belonging to the sea-shore.

Loam.—A mixture of sand and clay.

Loess.—A tertiary deposit on the banks of the Rhine.

LOPHIODON.—An extinct animal, of the order pachydermata, so named from the prominences on its teeth.

LYCOPODIACEÆ.—An extinct genus of plants, allied to the club-mosses, which occur on the moors and mountain-heaths of the north of England.

M.

MADREPORE. (Literally mother of pores.)—A term descriptive of corals which have superficial, star-shaped cavities or pores.

MAMMALIA; MAMMIFERA.—Animals which give suck to their young.

MAMMILLARY.—A surface studded over with rounded projections.

MAMMOTH.—The *elephas primigenius*, or primitive elephant.

MARL.—A mixture of lime and clay, of various degrees of hardness.

MARSUPIALS.—Animals which carry their young in a pouch, as the kangaroo.

MARSUPITE.—A zoophyte, allied to the crinoidea, occurring in the chalk.

MASTODON.—An extinct animal, allied to the elephant, the name being derived from its having tuberculated teeth, from *μαστος*, a breast, and *οδους*, a tooth.

MATRIX.—The mass or substance in which a fossil is embedded.

MECHANICAL.—Applied to deposits of sedimentary, as distinguished from those of igneous origin.

MEDULLARY.—Applied to the central pith of plants, and the vertebral column of animals.

MEGALONYX.—Great-clawed animal, allied to the sloth.

Megalosaurus. Great lizard.—An extinct gigantic carnivorous reptile.

Megatherium.—An extinct colossal quadruped, allied to the sloth.

Mica.—A simple mineral, one of the component parts of granite.

Miocene.—Middle tertiary strata.

Molares.—The double or grinding teeth.

Mollusca.—Animals with soft bodies, destitute of bones.

Monitor.—A lizard, found both recent and fossil.

Monocotyledonous.—A grand division of the vegetable kingdom, founded on the plant having but one cotyledon, or seed-lobe. (See p. 293.)

Multilocular.—Applied to many-chambered shells, as the nautilus, &c.

N.

Nodule.—A rounded irregularly-shaped mass, as a flint.

Normal.—Regular or legitimate; thus normal form means regular or legitimate form.

Nucleus.—The centre or point around which other matter is collected.

Nummulite.—An extinct many-chambered shell, resembling a coin; Lat. *nummus*, whence its name.

O.

Obsidian.—Volcanic glass.

Orthoceratite.—A straight many-chambered extinct shell.

Ossicula.—Minute bones.

OUTLIERS.—Detached portions of a main mass of strata. (See p. 249.)

OXYDE.—The combination of oxygen with a metal.

OXYGEN.—For a complete explanation, consult various works on chemistry. The beginner may be contented with knowing, that it constitutes the vital portion of the atmosphere, and enters so largely into the composition of rocks, as to constitute a considerable part of the solid strata of the earth. (See p. 218.)

P.

PACHYDERMATA.—An order of animals, including the elephant, rhinoceros, horse, pig, &c., distinguished, as their name, which is derived from the Greek, imports, by having thick skins.

PALÆONTOLOGY.—The science which treats of extinct animals.

PALÆOTHERIUM.—An extinct quadruped, allied to the tapir.

PALUDINA.—A fresh-water shell, of snail-like shape.

PLANORBIS.—A fresh-water shell, of discoidal form.

PLESIOSAURUS.—An extinct fossil genus of saurian or reptile, combining in itself the attributes of various tribes (see p. 507); approximating, however, more closely to the lizard than the fish, as the ichthyosaurus approaches more nearly to the fish than the lizard.

POLYPARIA.—Corals.

PORPHYRY.—An igneous rock. (See p. 206.)

PRECIPITATE.—The chemical deposit, in a solid form, of a substance held in solution by water.

PRODUCTA.—An extinct bivalve shell, found in the lower secondary rocks, now termed *leptæna*. (See p. 268.)

PTERODACTYLE.—An extinct winged reptile.

PUMICE.—Light, spongy, porous lava.

PYRITES.—Sulphuret of iron, a compound of sulphur and iron.

Q.

QUA-QUA-VERSAL DIP.—The dip of beds, from a common centre to all points of the horizon. (See p. 244.)

QUARTZ.—A simple mineral, composed of silex, in its purest form.

R.

RAMOSE.—Branched.

RETICULATE.—Resembling net-work.

RHOMB.—A quadrilateral figure, of diamond-like shape, having its four sides equal. (See p. 149.)

RHOMBOID.—A similar figure, having only two sides equal. (Ibid.)

RODENTIA. Gnawers.—An order of animals having a peculiar dentition, as the rabbit, hare, squirrel, rat, &c.

RUMINANTIA.—Animals which chew the cud or ruminate, (Lat. *rumino*, as the ox, deer, &c.

S.

SAURIAN.—An animal, belonging to the lizard tribe.

SCHIST.—The same as slate, from the Greek σχιζω, to

split, in allusion to the facility with which rocks of this texture may be divided or split.

SCORIÆ.—Volcanic cinders.

SECULAR. Used to describe the vast periods of geological changes. Thus secular refrigeration indicates the succession of ages, during which our planet has cooled down from its presumed original state of fluidity to its present solid condition.

SEDIMENTARY.—Deposited as a sediment by water.

SEPTARIA.—Nodules of clay, having their crevices filled with spar, and frequently some organic substance, as a nucleus, in the centre.

SERPENTINE.—A rock, the name of which is derived from its stripes and markings frequently resembling the skin of a serpent. In its normal form it is composed of diallage and magnesia.

SHALE or SCHIST.—Indurated slaty clay.

SILEX.—Flint.

SILICA.—The base of flint.

SILICEOUS.—Flinty.

SILICIFIED.—Changed to flint.

SILT.—The comminuted detritus transported by rivers.

STALACTITE.—The dripping of carbonate of lime. (See p. 546.)

STALAGMITE.—The same substance dropped on the earth. (Ibid.)

STRATIFIED.—Deposited in layers or strata.

STRATUM.—A layer of any deposit.

STRIKE.—The direction or line of bearing of strata, which is always at right angles to the dip. (See p. 242.)

SYENITE.—A variety of granite, in which hornblende

supplies the place of mica; so named from the city of Syene in Egypt, where it occurs.

SYNCLINAL AXIS.—The reverse of anticlinal, the point at which the strata converge towards each other (See p. 243.)

T.

TESTACEA.—Molluscous animals, as snails and whelks, scallops and oysters, which have a shelly covering, of which others are destitute.

TRACHYTE.—A variety of lava composed of feldspar, and often containing crystals of glassy feldspar. It frequently passes into other varieties of igneous rock.

TRAP.—Volcanic rocks composed of feldspar, augite, and hornblende. (See p. 206.)

TRILOBITES.—An extinct family of crustacea, having the back usually divided into three lobes.

TUFF.—Earthy volcanic rock.

V.

VEINS.—Fissures in rocks filled up by extraneous substances, either earthy or volcanic. (See p. 216.)

VERTEBRATA.—A great division of the animal kingdom, all which are furnished with a back-bone, as mammalia, birds, reptiles, and fishes, as distinguished from mollusca, articulata, crustacea, zoophytes, and insects, which have none.

VESICULAR.—Full of vesicles or cells.

U.

UNCONFORMABLE.—Strata lying in a different position from those on which they rest, or which rest on them.

Z.

ZOOPHYTES.—Animal-vegetables; a term incorrectly applied to corals and other animals, supposed to resemble plants in form.

INDEX.

TESTIMONIALS OF THE PRESS

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The present publication will be found not only adapted to the use of the student of geology, *but peculiarly to schools and classes of literary and scientific institutions;* indeed it is just such a work as will convey

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The ultimate design of this volume is very modestly stated in the preface. Mr. Richardson proposes simply to present the public, with an initial-book, popularly written and clearly constructed, containing, so to speak, the grammar of geology. Strange to say, there is no such work, countless as are our resources in the way of scientific treatises. Bakewell's admirable volume is not considered quite plain enough for mere beginners, and we believe it was the only volume of its kind in our language, until Mr. Richardson undertook the treatise before us. He may, therefore, be congratulated on having directed his attention to the subject, and the public may be congratulated on the way in which he has conducted it. The publication is well deserving of extensive circulation.—*The Atlas*, *June* 4.

The author of this publication, perceiving that the works already published on the science are most of them too difficult for beginners, and knowing that what is called geology is no separate department of knowledge, but a combination of all the studies of nature under one term, first instructs the reader in the associate sciences, before he touches on geology; and in separate treatises teaches the elements of mineralogy, physical geology, fossil conchology, fossil botany, and palæontology, before he enters on a description of the separate geological formations, and the structure of the earth itself. With the view to unite theory with practice, and to enable the beginner to ascertain his own progress, he adds a series of lessons at the end of each chapter, embodying its most important points of instruction in the shape of question and answer, a method admirably adapted not only for private students, but for *schools and classes of institutions*. * * * While the strictly elementary part of the volume is thus fitted for the pupil, the introductory chapters afford interest for the general reader, and contain information which even those more advanced in the science may be happy to acquire. The wood engravings which illustrate the work are more numerous than we remember ever to have seen in an elementary volume, and are most of them extremely spirited.—*Illustrated London News*, *June* 25, 1842.

The distinct systems of the great modern geologists are clearly ex-

plained; an accurate, and therefore valuable terminology is added, and even poetry is enlisted in the history of the science. Another and most important feature of this work is, that geological data are reconciled with the scriptural history of the creation; and while any sacrifice of scientific truth is carefully avoided, there is no presumptuous opposition of the imperfect evidence afforded by our hitherto most limited research to the authority of religion. The power of God in the creation is the theme of praise and wonder, and the root of instruction, in these pages.—*True Tablet*, *May* 28.

The author has embraced all that is really useful and instructive, and we conclude by a hearty recommendation of the work to *schools*, *mechanics' institutions*, and *students generally*.—*Illustrated Times.*

We do not hesitate to recommend this work to all persons desirous of obtaining an introductory knowledge of geology and its kindred sciences; they can scarcely fail of being pleased, like ourselves—*Dublin Literary Journal*, *May* 1, 1843.

Mr. Richardson's "Geology for Beginners,"—a volume which, without the slightest disparagement to any others, is entitled to be universally read and studied, by proficients as well as beginners.—*Dr. Pye Smith on Geology*, *second edition*, p. 40.

In reading, as we have with much pleasure read, Mr. Richardson's "Geology for Beginners," we could not avoid recurring to our early experience in this study with a feeling of regret, that we had not the facilities which this interesting volume is fitted to impart to the class for whom it is designed. Compared with the tortuous path we traced, and the many detours we made, a *cul de sac* being sometimes the reward of many days' wanderings, the path along which we have journeyed in Mr. Richardson's agreeable company has indeed been a royal road. We advert to our own early experience, only because we know it is that of many others, and because we are convinced that there is a large class participating in the general interest now felt in the wonders of geology, who really wonder whether the supposed difficulties of geology can ever be overcome * * * * * Be the cause what it may, the fact stands confessed, that much has yet to be done on behalf of those who are thirsting for knowledge, and by those who, having reached the fountains of intelligence, are best fitted to guide its streams into channels where they are most wanted, and will be most welcome. In Mr. Richardson the beginner will meet with a guide to his geological studies who has himself battled with the many difficulties which come in the

way of the inquirer, and, having conquered them all, consecrates his attainments to the benevolent work of facilitating the progress of others. The ladder on which he has ascended to his present position he leaves behind him, and, waiting at its summit, he encourages and guides the footsteps of all who are willing to follow him. Throughout his book he has carefully studied the improvement of his readers, and, in addition to the information he has himself given, has carefully indicated the sources from which farther treasures may be derived.—*Eclectic Review, May*, 1843.

We agree with the author of the work now under consideration, that, nothing detracting from the value of any of the works already published, an elementary introduction was required,—one which should dispense with technicalities, and treat geology as a science with which the public ought to be as familiar as general history, as it is only interchanging that of the nations of the earth for that of the earth itself. A few words will serve to convey a general idea of the plan of the work. In its pages will be found, successively traced, the definition and connexions of geology—its history and historians—its harmony—the bibliography of the subject—mineralogy—physical geology—fossil conchology and botany—palæontology—and sketches of the different groups of rocks; all of which are interspersed with numerous well-finished woodcuts. In addition, there is a feature which struck us as exceedingly concise and well-adapted, namely, the insertion of "Exercises" for the student, after each chapter, which in no way detract from the absolute value of the work, while they essentially contribute to its utility, as a guide-book and manual. There is yet another marked peculiarity which we should not mention; referring to the best collection of fossils, and works relative to each group of rocks, as those which are best calculated to afford a complete study of the particular riches of each. We think that Mr. Richardson has certainly gained the object which he proposed, and has produced a work which can be safely recommended to the student of geology, both for general clearness in arrangement, and completeness, embracing as it does the records of the most important facts in the science to this time.—*Geologist, July*, 1842.

We greet with pleasure the appearance of this book, which is, beyond doubt, one of the best elementary works that has been yet published on the subject of which it treats. The author, whose publications on other matters are known to the public, has bestowed great care on the

compilation of the volume, and on the lucid arrangement of the multifarious subjects which he has collated. His succinct elucidations of the science of mineralogy, and his chapter on fossil conchology and fossil botany, are excellent; and a number of exercises at the end of each division renders the volume peculiarly fitted for self-instruction, as well as for *a class-book in schools*, for which purpose, we understand, it has already been applied. A glossary of scientific terms is also a valuable addition.—*Brighton Gazette, June* 23, 1843.

The whole of these various treatises display such innate powers of mind, combined with such indefatigable labour and research, as must call forth the admiration and sympathy of the reader, and we cannot deny ourselves the gratification of congratulating the writer on having produced a work calculated at once to reflect honour on its author, and the institution to which he is attached, as well as to promote the cause of philosophy and science.—*Brighton Herald, June* 11.

In a judicious preface Mr. Richardson states his object to have been to produce a volume more expressly designed for the beginner than any yet published. He has fulfilled this object in a highly successful manner, and has lastingly established his name and fame as a writer on science.—*Brighton Guardian, June* 15.

We had anticipated, from the talent and perfect knowledge of the science of geology displayed by Mr. Richardson in the delivery of a course of lectures some months ago in this vicinity, and which at that time excited much interest, that his work would be one of considerable merit, nor have we been disappointed; his book is decidedly the best that has been produced as an introduction to geology.—*Stamford Mercury, June* 10.

We cannot withhold our admiration of the industry, talent, and information displayed in the work. The very attempt is highly meritorious, indicating powers of mind possessed by comparatively few. To compose a separate treatise on subjects so difficult and obscure as those which constitute the elementary studies of geology, and the complete acquirement of which, as the author states, would each demand the labour of a life to write a manual of such sciences as mineralogy, physical geology, fossil conchology, fossil botany, and palæontology, which are contained in the present volume, constitutes an effort in the highest degree honourable to its author. And when he adds that the work has been written not amid the advantages of ease and labour, but

the cares and difficulties of daily exertion and toil, we cannot refuse our admiration of a performance attempted under so much difficulty, and achieved with so much success.—*Lincolnshire Chronicle, June* 10.

Both the design and execution of this work reflect great credit on the author. Among the many admirable treatises on this popular science which have hitherto appeared, this is the first that can with truth be designated "Geology for Beginners." Several former works, some of them written by the first geologists of the day, are excellent, so far as geology is concerned; but they are seldom sufficiently simple for general readers, especially young persons, and the reason is obvious—they do not "begin at the beginning." Perhaps no branch of human knowledge is so completely dependent on kindred studies as geology, and a work was much wanted to prepare the mind of the student for the reception of the fundamental facts of geology, by imparting some information on the collateral sciences. This want has been supplied by the work before us, and the judgment displayed by the author in condensing so much useful matter into so small a space is highly conspicuous. There is one feature in this volume which will add greatly to its usefulness, namely, the exercises at the end of each chapter; these are not merely questions confined to the text, on the plan of the interrogatory school-books; but are admirably calculated to elicit habits of thought and observation. It is evident, that nothing can be better adapted than exercises thus arranged for creating those habits of investigation so necessary to the progress of a young geologist, and, *with this manual, geology might be introduced with advantage among other branches of instruction in public schools.* This volume is well and extensively illustrated: beside the frontispiece, by Martin, there are about two hundred and fifty engravings. It is inscribed, by permission, to his Grace the Duke of Rutland, and such permission is alike honourable to his Grace's judgment and feelings.—*Birmingham Herald, June* 16.

The plan is excellent, and, we are bound to add, the execution is equal to the design. After some preliminary observations, in which the author successfully vindicates the practical importance of the study, and shows it to be no mere hypothetical or visionary pursuit; but to be intimately associated with the welfare of society and the arts of life, he presents the reader with a manual of the distinct studies of mineralogy, physical geology, fossil conchology, fossil botany, and palæontology, together with useful practical directions for generally cultivating the science, and at a price which can scarcely prove remunerative, considering

the cost of the illustrations. We thus possess, in a single volume, either the substance of the most valuable treatises on these subjects, or instructions for the most efficacious and best mode of studying them. Having by this means imbued the mind of the pupil with the requisite preliminary instruction, Mr. Richardson then gives a sketch of the respective geological formations; and having rendered the reader acquainted with the principles of natural science, introduces him to nature herself, and her harmonies and beauties, as they are developed in the splendid creation around us. We heartily congratulate the writer on having produced the best and cheapest elementary treatise on the science yet offered to the public.—*Cheltenham Free Press.*

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